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ABSTRACT

Reported is an experiment on instructional episodes organized around the planetary atomic model. The study involved 236 children of eight self-contained classes, four of which were reference classes in each of 3rd, 4th, 5th, and 6th grades. The purpose was to investigate the feasibility of presenting these activities within a cognitive hierarchy as early as the middle elementary grades. The two cognitive objectives were designated as factual-conceptual and inferential, each being further classified into the background category and the category pertaining to the model. The 48-item multiple-choice test used in pre- and post-measurements was at the middle-elementary reading level and subjected to jury validation. Regular non-science teachers conducted the experiment 30-45 minutes daily for a seven-week tenure after completion of a 12-hour training period. Statistical analyses showed the presence of satisfactory results. Further research was recommended for the determination of predictive indices for mental abilities and cognitive achievement, the development of various teacher training modes, study of implementation in schools with varying social-economic-ethnic patterns, and study of the feasibility of presenting other science conceptual schemes in elementary schools. (Diagrams may reproduce poorly). (CC)

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AN INVESTIGATION IN ELEMENTARY SCIENCE CURRICULUM, EMPLOYING A CONCEPTUAL..

SCHEMES APPROACH

S. H. Steinberg, 1970

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AN INVESTIGATION IN ELEMENTARY SCIENCE CURRICULUM, EMPLOYING A CONCEPTUAL SCHEMES APPROACH

by

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B.S., Syracuse University, 1953
M.S.(Ed.), Syracuse University, 1954

DISSERTATION

Submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Science Education in the Graduate School of Syracuse University, January 1971

Approved Alfred Nesbitt

Date 16 December 1970

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CHAPTER I

INTRODUCTION

In the wake of the Sputnik shock and the accompanying concern over alleged shortcomings in all levels of U. S. education, Jerome Bruner came forth with a startling hypothesis; it has been especially challenging to those who are responsible for elementary school curricula. He stated:

> ... the foundation of any subject may be taught to anybody at any age in some form. (Bruner, 1960, p. 12)

At first reading it appears hyperbolic. Nevertheless, despite the implied variables, it generates a certain compelling consideration. This is especially so for those who have experienced with children their intense curiosity in natural phenomena and who realize the possibilities this curiosity opens for curriculum innovation.

Shamos (1966) has called for science curricula which maximize the presentation of subject foundation based on major conceptual schemes or models. He asserted that:

> ... conceptual schemes, models, theories... are the creation of man, not of nature. They represent the pinnacle of explanation in science, and must be classed among the greatest of man's purely intellectual achievements. Such unifying theories are the main goal of science and should be at the focal point of a science curriculum. (Shamos, 1966, p. 29)

One such conceptual scheme of monumental consequence has been the Bohr-Rutherford atomic model, or planetary atom. Frisch and Thorndike have declared:

> The triumph of the Bohr-Rutherford atom in classifying the elements of the Periodic Table on the basis of their electron structure was one of the greatest achievements of all time. (Frisch & Thorndike, 1964, p. 11)

Although the planetary atomic model has been supplanted by more fruitful ones in advanced scientific enterprises, the planetary model remains as the instructional paradigm for introductory studies. The benefit to learners of simplified, modified or recast content has been noted by the editors of Taxonomy of Educational Objectives (1956):

> The organization the specialist finds most useful is not necessarily the organization that provides the easiest learning path for the student. (Bloom, et al., 1956, p. 37)

The planetary atomic model is useful as a model to explain basic chemical, electronic and nuclear phenomena on the vocational and technical level. Moreover, it is the simplest valid picture on which to build a Periodic Table of the elements; it is this reason which has preserved the planetary model as a profound paradigm for instructional purposes. In children's scientific literature the planetary atom is uniformly recommended for elementary and early secondary (including biology and earth science) science curricula. However, the extent and depth of approaches show great variation from curriculum to curriculum. Smith and Anderson (1960) commented on the confusion in placement of science content:

> ... the knotty problem of articulation between the elementary and secondary school has not been solved at the present writing. (Smith & Anderson, 1960, p. 1219)

Since this lament was published, the presentation of atomic principles has become even more confused. Several examples of the placement confusion follow. The New York State Education Department through its Bureaus of Secondary Curriculum Development and Elementary Curriculum Development has been revising the K-9 science curricula on a continuous basis since 1962. In early secondary science there have been produced 13 comprehensive unit-type blocks of science study which are recommended in various sequences. The use of the blocks and their sequence is optional for the needs and wants of local curriculum builders. Compared with an earlier curriculum, the blocks provide greater content depth. They bring large portions of what was formerly Regents Examination science content into the junior high, including studies in chemistry and nuclear energy.

Regarding the elementary level, the New York State Bureau of Elementary Curriculum Development in its series of publications Science for Children K-6 (beginning 1964) recommends introduction to the planetary atom at the 6th grade. This introduction relies mostly on descriptive activities which include basic quantitative exercises on atomic weight (mass), atomic number, and arrangement of electrons in simple circular orbits. However, at the early secondary level, possible difficulty with atomic abstractions is recognized in a statement from one of the blocks, Chemistry of Matter:

> Pupils will vary in ability to grasp concepts in this area [atomic studies]. Teachers should use good judgment in deciding the depth to be taught. (University of the State of New York, Education Dept., 1963, p. 37)

Curiously, no similar admonishment is given in the elementary syllabus on atomic studies though the content of the two curricula are nearly identical in the introduction of a basic atomic model. The early secondary block goes on to introduce the Periodic Table as a prelude to understanding simple chemical reactions.

The placement and recommended depth of atomic studies is further confused at the national level by recommendations of the Elementary School Science Project (ESSP) of the University of Illinois. In its publication Astronomy: The Message of Starlight (ESSP, 1965) a most rigorous planetary atomic model is suggested for elementary science. In a statement of purpose, ESSP seeks to:

> ... foster the development of course content materials that reflect a modern orientation to science... (ESSP, 1965, preface)

and further states:

> We hope that children and teachers encountering this material for the first time will perceive the economy and intellectual powers of these ideas which encompass a broad array of events in the physical world. (ESSP, 1965, preface)

In the ESSP edition quoted, the depth of treatment of some of the atomic studies is startling. Activities related to the planetary atomic model pursue quantitatively such features as: the relation between emmission lines and electron jumps; wavelengths of electron radiation; the dependence of photon wavelength upon photon energy and, hence, presents the duality concept needed

to interpret diverse phenomena associated with light. There are no grade levels or mental ages recommended for such content, but it is prepared for inclusion somewhere, unspecified, in the elementary science curriculum.

Smith and Anderson (1960) noted that there have been numerous investigations of grade placement for science experiences. Nevertheless, there is a dearth of reported studies that have been directed toward organizing and evaluating feasible classroom activities for elementary children which employ a major conceptual model of science as a basis for applying cognitive experiences about the model to making inferences about new or unfamiliar phenomena. Further, a search indicates that no study has been reported which investigates the relation between a measure of scholastic ability by sex, and levels of a cognitive hierarchy relevant to the planetary atomic model that may be successfully presented to intact elementary classes.

The purpose of the study reported here has been to organize and test the feasibility of a sequence of instructional episodes for middle elementary and pre-secondary classes which lead to and include cognitive experiences pertaining to the planetary atomic model. Moreover, certain activities are applied to understanding the nature of selected physical phenomena. Pupil attainments in a specified cognitive hierarchy are analyzed and should be of interest to elementary and junior high school teachers, curriculum workers, and publishers of textbooks and other teaching aids.

CHAPTER II

REVIEW OF RELATED LITERATURE

Many years have passed since an influential committee of science educators, under the aegis of the National Society for the Study of Education (1932) advocated the development of an articulated science program from kindergarten through the entire secondary school. In the years immediately following the NSSE inchoation, descriptive science curricula were formulated by some agencies and a few individuals, but a dearth of it was implementated in elementary school classrooms. Furthermore, prior to the 1950s little can be found in the literature which reports efforts to synthesize classroom science experiences that combines science, as it is understood and created by practitioners of science, with the way that children at different levels of maturity and experience can efficiently internalize and apply science content.

In 1947 NSSE turned its attention to the formulation of major objectives that should be applied to the construction of articulated science programs. Several comprehensive attempts at grade placement of science concepts were reported (see citations to follow), but it was the shock of Sputnik that directed anxious attention toward the development of science curricula for the elementary school.

In recent years federal funding has provided the main

sustenance for investigation of new elementary science curricular patterns by professional societies, state education departments, regional educational agencies, and by individuals. In addition, private publishing houses have developed and sold "complete" programs in elementary science. Compared to secondary school curricula studies, elementary science education has been tardy in creative efforts. Nevertheless, nine large-scale curriculum studies in elementary science in various stages of investigation have been summarized by Karplus and Thier (1967); their compilation does not include the Conceptually Oriented Program in Elementary Science (COPES) which was initiated in 1967 and expanded in 1969.

The review of literature pertaining to the present study is reported in three parts: (1) What rationale underlies the development of learning experiences based on major conceptual schemes of science for the elementary school? (2) What studies have been reported that bear on the purposes of the present study? (3) What problems are faced in design of curriculum studies and how may they be resolved?

1. What Rationale Underlines the Development of Learning Experiences Based on Major Conceptual Schemes of Science for the Elementary School?

The re-discovery of the Piagetian school of developmental psychology has re-generated interest in placement of science content in the elementary curriculum. Piaget's collaborator, Barbel Inhelder, has been quoted by Bruner (1960) regarding readiness for experiences in science content:

> ... it seems highly arbitrary and very likely incorrect to delay the teaching, for example of Euclidian or metric geometry until the end of the primary grades,.... So too with the teaching of physics which has much in it that can be profitably taught at an inductive or intuitive level much earlier. Basic notions in these fields are perfectly accessible to children of seven to ten years of age, provided that they are divorced from their mathematical expression and studied through materials that the child can handle himself. [italicized in original] (B. Inhelder, quoted in Bruner, 1960, p. 43)

Bruner (1960) assumes the position of an environmentalist in viewing broad opportunities for curriculum innovation. He asserted that:

> ... the intellectual development of the child is no clockwork sequence of events; it also responds to influences of the school environment. Thus instruction in scientific ideas, even at the elementary level, need not follow slavishly the natural course of cognitive development in the child. It can also lead intellectual development by providing challenging but usable opportunities for the child to forge ahead in his development. Experience has shown that it is worth the effort to provide the growing child with problems that tempt him into next stages of development. (Bruner, 1960, p. 39)

The knowledge explosion has induced the National Science Teachers Association (1962) to support a particular position in curriculum innovation.

> ... the great conceptual schemes such as conservation of energy, the kinetic theory of heat, the atomic theory of matter, and the biochemical theory of heredity should be at the focal point of any science curriculum. (NSTA, 1962, p. 33)

In his continuing search for the essence of a viable theory of instruction Bruner (1963) has taken a stance on the objectives of curriculum development which parallels that of NSTA:

> ... a theory of instruction should [in part] concern itself with the optimal structuring of knowledge ... for any body of knowledge there is a minimal set of propositions, statements, images, from which one can best generate the rest of what exists from within that field. Armed with the minimal set, the economical core of the field, you can reconstruct the detail. For example, armed with a few things more than just conservation theorums, the conservation of mass, energy, momentum and the rest of it, a great deal of physics can be reconstructed. This is the "guts" of physics. (Bruner, 1963, p. 525)

These viewpoints do not enjoy universal acceptance. The conceptual schemes approach to building elementary science curricula was criticized by Ausubel (1965) who wrote:

> From a developmental standpoint the... conceptual schemes are not equally suitable for <u>all</u> age levels; some subject matter principles cannot be transmitted to young children no matter how they are presented. ... at the elementary level... the child's dependence on concrete empirical experiences makes unfeasible such suggestions as teaching him "first principles", basic abstract laws or methodological canons of science either at the level of generality contemplated in this position paper, or divorced from his everyday experience. (Ausubel, 1965, pp. 263 & 264)

Yet there is nothing in Ausubel's paper that buttresses his opinion with citations of research. Moreover, little that is generalizable has been reported from the recent large-scale investigations in elementary science curricula or from the literature that makes an earlier observation by Bruner (1960) any less relevant:

> There is a surprising lack of research on how one most wisely devises adequate learning episodes for children at different ages and in different subject matters. There are many questions that need answers based on careful research... (Bruner, 1960, p. 49)

It might be contended that failures in curriculum research are not reported, or worse, are obscured in some manner; perhaps, but until shown the evidence, such an argument must be classed as conjecture.

The viewpoint held by Ausubel is being countered by a recently innovated curriculum study based on the major conceptual schemes of science. The Conceptually Oriented Program in Elementary Science (COPES) offers this rationale:

> Our approach is to stress the great conceptual schemes, to place them uppermost in the minds of students, and to relate all else in science, wherever possible, to these central ideas. We believe that such an approach may have genuine survival value, that long after he has forgotten the facts of science an individual exposed to such a curriculum may at least possess the main conceptual schemes and retain some feeling for the nature of the scientific enterprise. (COPES, 1967, brochure, pp. 2-3)

In directing the focus of their efforts upon children in the elementary school, spokesmen for COPES claim that:

> ... it is in the elementary grades that the greatest impact can be made in science education... the motivation and ability of children in the primary grades to deal with scientific concepts appear to have been grossly underestimated. In these formative years, when minds are so receptive to new ideas, we believe it should be possible to develop a foundation in science that will remain a permanent part of the individual's intellectual life. (COPES, 1967, brochure, p. 3)

In conclusion, COPES' spokesmen (1967) take the position that the several other major projects initiated in the past decade to develop elementary science materials are not designed to meet the objectives set forth under the COPES formula. In pages to follow the COPES investigation will be compared to that of the present study.

Piaget's theory of intellectual growth has been reflected, at least in part, in the organization of nearly all recent research in development of elementary science curricula. Piaget has identified several stages of intellectual capacity which children can be expected to pass through before culminating in the reasoning powers that are identified with the maturely functioning adult. Of profound interest to educators is the evidence that the inception of an identifiable state of intellectual capacity can be nurtured by environmental experiences. Furthermore, the quality and completeness of each stage and thus the readiness for the next stage of intellectual development is plastic to the influence of the environment. (Piaget, 1960)

Influenced by Piagetian theory and findings, curriculum researchers in elementary science have sought to identify viable heirarchies or levels of experiences that must be internalized (learned) by the child before he can be expected to proceed to, and succeed at the next developmental stage.

Relevant to the present study are two hierarchies; one is Bloom's (1956) Taxonomy of Educational Objectives, and the other is described by Gagné (1956) in The Conditions of Learning. In the present study the levels of content organization of the classroom activities are in part drawn from those described in the Taxonomy which is organized into six major classes listed here in increasing order of cognitive complexity: (1) knowledge (factual), (2) comprehension, (3) application, (4) analysis, (5) synthesis, (6) evaluation. In the present study the hierarchy

of cognitive complexity progresses at least through the third class, namely, application. The hierarchy is embodied in certain classroom activities which are oriented towards applying facts or knowledge and relations between facts or comprehension to unfamiliar phenomena. Such a rationale is suggested by the Taxonomy (1956) where it is stated:

> Although information or knowledge is recognized as an important outcome of education, very few teachers would be satisfied to regard this as the primary or sole outcome of instruction. What is needed is some evidence that the student can apply the information to new situations or problems. (Bloom, et al., p. 38)

A hierarchy of general conditions for learning has been suggested by Gagné (1965). The hierarchy consists of eight parts with success at any one stage having as a prerequisite success at the preceding stage. Gagné has identified a specific hierarchy for science. It is made up of five phases which culminate in the highest realm of scientific (and general) learning proficiency, namely, problem solving. Gagné has recognized an association between a conceptual schemes science curriculum and a hierarchical framework to organize it. He states:

> Science learning... has a hierarchical structure that is supported by a number of concepts and principles that are not content-specific; rather they are general to the study of any and all sciences. (Gagné, 1965, p. 190)

In the present study middle elementary and pre-secondary classes were presented episodes based on a hierarchy of facts, concepts, and inferences leading to and pertaining to the planetary atomic model for application to understanding the nature of selected physical phenomena. In parallel Gagné's hierarchy of learning in

science includes factual and conceptual learning within his first three phases, namely: (1) basic types of learning (2) multiple discrimination learning (3) conceptual learning. Concluding the parallelism, inferential learning is, in Gagné's system a subdivision of the fourth phase, namely, principles. Gagné has defined principle as "... a chain of two or more concepts." (Gagné, 1965, p. 52) He posits that:

> A rather large number of principles could be named that are common to all sciences... these... seem to fall into logical categories and these might well be considered as topics of elementary science. (Gagné, 1965, p. 185)

Those logical categories of which Gagné speaks are classifying, measuring, space-time relationships, communicating, and inferring.

The highest level of science learning, problem solving, is not considered in the present study. Gagné has commented on the misinterpretation of the so-called problem-solving method for practical classroom situations:

> Some writers and practitioners have treated problem solving as though it could be achieved with a minimum of instruction and prerequisite knowledge of principles. To be successful problem solving must be based on the knowledge and recall of the principles that are combined in the achievement of the solution, the higher order principle. Of course, the individual learner may be [given] a problem which is "beyond him" in the sense that he must acquire all the subordinate principles himself before he achieves a solution. ... to advocate such an approach as a practical learning method makes no sense. (Gagné, 1965, p. 165)

2. What Studies Have Been Reported that Bear On the Purposes of the Present Study?

In the era just preceding the current large scale investigations in elementary science curricula, several studies were reported that have a bearing upon the present study, either in the effort to grade-place a concept of physical science, or in the design of the study cited.

In a study suggested by Fletcher Watson, McCarthy (1951) investigated the problem of teaching "profitably," for the first time, facts and concepts about simple machines. The study was reported in Science Education, 1952. The technique of investigation included: a pre-test wherein the children were encouraged to manipulate the apparatus to arouse their interest and to ascertain their background; teacher demonstrations followed by manipulations by the children; discussion to indicate understanding; a post-instructional test consisting mostly of pictures given six weeks later. The validation testing was done in the 2nd grade of a Boston school. Grades K, 1, 3, 4 were tested later, one child at a time. The conclusions: The influence of mental age on ability to understand is pronounced; work as defined in physics is a suitable topic for second graders; children find it easier to demonstrate and answer on apparatus than to express in words, though their manipulations are clumsy. The authors of the report on the McCarthy study in conclusion, asserted:

> Similar investigations could establish the suitability of other scientific concepts for definite grade levels. It is obvious that tens of thousands of such investigations could be planned and carried out. (McCarthy, reported in Science Education, 1952, pp. 253-254.)

The enormity of such an enterprise staggers comprehension, though the processing of the data would be relatively manageable. One wonders if these remarks were designed to encourage such enterprises, or was there a tongue-in-cheek connotation?

A study using 15 New England schools from a stratified sample of classes was reported by Oxendine (1953). He endeavored to define at what grade level maximum learning can be expected from the results of his teaching the physical science principle "Sound is Produced by Vibrating Material." The results indicated that older children display greater comprehension. In reference to the present study, Oxendine's test items were not analyzed by levels of a cognitive hierarchy.

Only one research study of a comprehensive nature has been reported which has used the theme of atomic energy as the basis of curricular investigation. Furthermore, it is the only multiclass study in which the investigator seems to have clearly stood aside while the regular classroom instructor used the new materials. Reid (1952) analyzed the understanding of certain atomic energy "concepts" by fourth, fifth and sixth graders. Reid's "concepts" were derived from the interests manifested by a pilot group and were entitled, the atom, atomic fission, atomic pile, atomic power, and tagged atoms. The emphasis was

on knowledge of technology as the outcome of instruction. The classes were taught by their own instructors using Reid's plans which were almost solely lecture-recitation oriented, coupled with one piece of popular literature on atomic technology. Pre and post testing of experimental and control classes ultimately led to data that supported the contention that fifth and sixth graders could successfully acquire the content. Reid pointed out that no experimental studies on presentation of concepts of atomic energy had been done up to the time of his investigation and that it appeared to offer:

> ... a practically untouched field for the educational research worker. (Reid, 1952, p. 46)

In the intervening years little of experimental consequence has been reported which identifies what aspects, if any, of the planetary atomic model can be presented in the elementary school. Reid's investigation did not analyze the ability of the pupils to demonstrate their knowledge of the atom (his first "concept") by application to new or unfamiliar phenomena.

Pella and Solberg (1958) reported evidence that elementary children could benefit from instruction in atomics. One class of fifth graders was taught a unit on atomic energy using multimedia methods of instruction. The pupils displayed a much greater post-instructional understanding of the topic as indicated by the results of writing exercises. In reference to the present study, the Pella and Solberg report makes no direct mention of

employing the planetary atomic model to infer about the nature of new or unfamiliar physical events.

The concepts of atomics held by certain elementary children was investigated by Young (1958). Third and sixth graders were examined by interview and questionnaire respectively to determine their knowledge at three levels: these ranged from didn't know or a misconception, through the substantially correct level. The findings, reported only in percentages from 75 third graders and 68 sixth graders indicated that boys' knowledge at all levels was greater than girls'. A sixth grade class that had previously studied atomics knew much more than all other pupils in the study. The investigator concluded that the study of atomics should begin before the early secondary grades. (Young, 1958, p. 538)

The problem of accounting for the teacher variable has loomed large in the reluctance of critics to accept generalization from the results of research in grade placement. Harris (1964) reported A Technique for Grade Placement in Elementary Science in which he used sound tape instructions for presentation of activities relevant to the kinetic-molecular theory of heat to teachers and pupils of grades 4, 5, 6 in a laboratory school. The Harris study was criticized in extensive detail by Shoresman (1964) who questioned aspects of design, technique and interpretation. Underscoring Shoresman's analysis was:

> ... a big question pertaining to the long run value of research dealing with the grade placement of science concepts. (Shoresman, 1964, p. 77)

Much of Shoresman's criticisms appear to have been met and overcome in a report on a recast study by Harris and Lee (1966). However, Shoresman's "big question" was unanswered. In summary, the Harris and Lee (1966) investigation reported that mental age is associated with success in learning concepts about the kinetic molecular theory of heat. There was no indication that pupils were expected to apply the concept to new or unfamiliar situations.

Ashbaugh (1968) has reported an investigation to arrange in order of difficulty a series of concepts in geology for intermediate grade pupils. An examination of the concepts listed for the study reveal a considerable number that have as a basis one or more of the major conceptual schemes of science. Ashbaugh used multiple analysis of covariance to test the overall null hypothesis that no significant relationships existed between a pre-test, sex, age, instructional group, intelligence, past science achievement, socio-economic status and the attainment of the concepts. Further, the investigator used t-ratios of differences with selected pairs of means to compare grade level achievement between control and experimental groups. A difficulty index was computed for each concept. The report implied that the investigator taught all the experimental classes. He used primarily the method of demonstration. The investigator somewhat expansively concluded:

> Demonstration teaching [was effective in arousing] interest in science, helped children solve problems, encouraged slow and rapid learners, and aids students in applying what has been learned to new situations. (Ashbaugh, 1968, p. 196)

Most of that quoted seems to be based on the investigators' own observations. In particular, the observation in the last phrase is not directly supported by specific design and data.

A study reported by Shrader (1968) was designed to determine if fifth and sixth graders in a laboratory school could understand the principles of chemistry that are taught to a regular class in introductory college chemistry. The children were taught by methods commensurate to their level and by a trained teacher other than their regular instructor, but previously known to them. No comparison was made between methods and teachers. The report displayed a table showing the number of times a particular scientific term was "touched upon" in a multiple choice pre and post-instructional test. It was not possible to print the lesson plans in the report, but the following terms, relevant to the present study were used: atom, atomic nucleus, atomic weight, electron, isotope, and neutron. There was no precise or apparent indication of level of learning expected or carried out, but the implication was that it approached the level of an introductory college chemistry course both in lecture and laboratory orientation. The expected differences were manifest between experimental and control classes at the elementary level, and between pre and post-instructional results at the college level. The elementary

experimentals showed very significant gains, indicating that for these children it was possible to learn introductory college chemistry. The investigator noted that for the most part the children's interest was high and that they were attentive during science periods of an hour each day. It was not reported how laboratory experiences were structured for such a time interval.

The Conceptually Oriented Program in Elementary Science (COPES, 1967) employed the viewpoints of scientists, psychologists, and science educators to build a hierarchy of concepts which lead to the major conceptual science theme, conservation of energy, for grades K-6. Two sets of tests to measure children's understandings were produced; one set measured understanding of key terms and the other measured understanding of higher order concepts, mostly via pictures. After preliminary try-outs, formal testing of the materials was performed by two special teachers working with 700 elementary school children in two public schools.

A two year pilot study to develop the materials for one conceptual scheme, conservation of energy, has been reported (COPES, 1968). The investigators claim:

> The most significant implication of the pilot study is the feasibility of developing materials that will contribute to children's understanding of other conceptual schemes of science. (COPES, 1968, newsletter no. 3, p. 1)

Nevertheless, COPES admits to a contingency in the use of the materials:

> Reactions from classroom teachers associated with the pilot study indicate that most elementary school teachers lack the background in science needed to handle these materials adequately. (COPES, 1968, newsletter no. 3, p. 1)

Such a contingency may limit applicability of the rigorous COPES materials except possibly in schools staffed with aggressive science specialists. The implementation of an expanded program has been announced by COPES (1970). However, as yet, it cannot be said that COPES has produced elementary science materials which are valid, consistent, and applicable to on-going, self-contained classroom settings. The need for such materials persists.

3. What Problems Are Faced in Design of Curriculum Studies and How May They Be Resolved?

Writing in the era immediately preceding the rise in elementary science curriculum experimentation, Mallinson (1961) commented:

> It is becoming increasingly apparent that attempts to "grade place" science subject matter in the elementary curriculum are indeed futile.... The rapid accumulation of scientific knowledge and the increasing sophistication of modern children render ephemeral within a short time many of the topics that are "grade-placed once and for all." (Mallinson, 1961, pp. 258-259)

She further asserted that:

> ... any topic or concept of science can be taught at any grade level providing the teacher expects a depth of understanding consistent with the maturity of the elementary student. (Mallinson, 1961, p. 259)

A question arises: where are all those sophisticated children (much less their sophisticated teachers) that Mallinson suggested would be appearing in modern classrooms? Most children can be readily and intensely stimulated to sophisticated interest in science, but their initial understandings are, as ever, almost universally meager. The rapid accumulation of scientific knowledge noted by Mallinson, would seem to further the need, indeed be the justification for the development of a curriculum built around the major conceptual schemes of science. In scientific enterprises, both theoretical and practical, the conceptual schemes have displayed great utility in description, prediction and modification of physical and biological events... and in the process the schemes themselves have been rendered changed and modified. As such, a conceptual schemes curriculum would seem to be the most efficient and relatively lasting means to immerse children in the ways and wonders of scientific thought and enterprise.

The second statement quoted from Mallinson paraphrases Bruner's famed hypothesis. However, if the statement's prologue is correct, the epilogue is subject to question; it is not at all clear, how an individual teacher, without the benefit of findings from curriculum research, would be able to judge what experiences

in science could provide a depth of understanding consistent with the maturity of his students. Mallinson has suggested a spiral format for ordering elementary science experiences based on three levels of maturity. Her viewpoint may have had some influence in inciting the present widespread interest in elementary science research.

Gallagher (1967) has commented on what orientation curriculum studies should take:

> Curriculum evaluation is a large term with many meanings. Most of the new curriculum projects have embarked on some efforts in this direction and more demands for systematic evaluation are sure to come as the increasing costs of such programs require justification. One type of evaluation has been to compare old and new curriculum across as many classes as one can control, and this sometimes can involve thousands of students. This investigator does not believe that such massive comparisons yield much information to the persons struggling to improve their curriculum programs. There are just too many variables interacting in the macrocosm of these many classrooms and different communities to allow for precise analysis.
>
> Instead the answer would seem to lie in clear delineation of the microcosm of the individual classroom, observing as precise and limited goals as possible. (Gallagher, 1967, p. 18)

Gallagher moves to the heart of the problem in curriculum research stating:

> ... those interested in curriculum development have not finished their job when they have packaged a cognitively valid and consistent set of materials. They must establish, in addition, how these materials are operationally introduced in the classroom environment. (Gallagher, 1967, p. 18)

The problem that confounds in curriculum research is to design an investigation which may yield generalizable findings, yet warrants the applicability of the findings to a specific classroom situation. Campbell and Stanley (1963) have suggested an approach in reference to research on teaching; it is submitted that their suggestion also has virtue in the design of curriculum studies:

> Often stringent sampling bases occur because of the inertia of experimenters who do not allow a more representative selection of schools the opportunity to refuse to participate. Thus, most research on teaching is done in those schools with the highest percentage of university professor's children enrolled. While sampling representativeness is impossible of perfect achievement and is almost totally neglected (in most studies appearing in the Journal of Experimental Psychology, for example) it both can and should be emphasized as a desideratum in research on teaching. One way to increase it is to reduce the number of students or classrooms participating from a given school or grade and to increase the number of schools and grades in which the experiment is carried on. It is obvious that we are never going to conduct experiments on samples representatively drawn from all United States classrooms, or old world classrooms. We will learn how far we can generalize an internally valid finding only piece by piece through trial and error of generalization efforts. But, these generalization efforts will succeed more often if in the initial experiment we have demonstrated the phenomenon over a wide variety of conditions. (Campbell & Stanley, 1963, p. 189)

In the present study, 26 school districts in the Eastern Finger Lakes Region of New York State were given the opportunity to volunteer. The area covers small city and town, suburban and rural schools with a wide socio-economic mix. One small-town-rural school volunteered. The teachers of the

experimental classes used the materials in their own classes. As in the study reported by Reid (1952) the normal classroom situation was preserved in total.

Campbell and Stanley (1963) have commented upon investigator-teachers who are alien to a particular school or classroom setting:

> ... as a result of personal observation of experimenters who have published data in spite of having such poor rapport that their findings were quite misleading, the present authors are gradually coming to the view that experimentation within schools must be conducted by the regular staff of the schools concerned whenever possible, especially when findings are to be generalized to other classroom situations. (Campbell & Stanley, 1963, p. 191)

Yet, the use of regular volunteer teachers introduces a certain bias. Schmitt et al., (1966) writing on Problems and Resolution in Design and Execution of Curriculum Research have noted that:

> ... there are usually more pressing requirements for school district's time and money than educational research... procurement of participants is likely to be more a matter of persuasion than of selection, and this factor has important implications for the generalization of research findings. (Schmitt et al., 1966, p. 138)

Nevertheless, these writers are not unmindful of the motivational effects that may accrue from the use of volunteers:

> ... the influence upon research criteria exerted by the mere consciousness of participation [Hawthorne Effect] ... is a significant problem in most curriculum research.... There are no truly adequate controls for it in dealing with many problems, and perhaps, since its effects are routinely positive, educators might be better advised to curry "Hawthorne" rather than to attempt its control. (Schmitt, et al., 1966, p. 139)

The teachers in the present study were chosen by their principal from a larger group of volunteers. Salinger (1966) in a progress report on the Elementary School Science Curriculum Project has commented on the relation of teacher zeal as a requisite to successful learning experiences:

> ... we hope that our own enthusiasm may be successfully transmitted to the teacher. Enthusiasm is contagious; surely the teacher's own eagerness closely correlates with the successful use of our materials. (Salinger, 1966, p. 39)

Obviously, the volunteer brings enthusiasm to the situation, and to that extent a bias is introduced. It is a bias, nevertheless, that one wishes normative in all classrooms. Thus, it is submitted that at worst, necessity obtains a virtue.

A frequent criticism of curriculum research has been noted by Schmitt et al., (1966):

> ... criticisms of curriculum... research focuses on failure to control for differences in teaching ability. Since there is little agreement regarding the characteristics of an effective teacher, matching for teachers is better not attempted, and the only reasonable alternative is to have each teacher serve as his own control. (Schmitt et al., 1966, pp. 138-139)

If it is agreed that an ability to motivate and lead children is likely to be found in those who volunteer for such a study, then it is submitted that a certain homogeneity in teaching ability has been operative in the present investigation.

In a previous discussion, Shoresman's (1964) criticism

of Harris' (1964) study was cited. In reference to the Harris (1964) report, Shoresman questioned if relative understanding between grades can realistically be compared when "identical" means of presentation and identical tests are employed. In the present study the lessons are structured alike for both grade categories, namely, middle elementary and pre-secondary. However, each activity and its measurement of attainment has been assigned a specified level in a cognitive hierarchy; assignment of the levels was validated by an expert jury.

It is recognized that a special wide-band of variables exists in otherwise unencumbered self-contained classrooms. These variables are associated with the personal interactions between and among the teacher, groups of children, and individual children. Furthermore, these interactions have a differential basis as to when they take place and their relative intensities. Such a complex of interactions makes one teacher's class milieu different from another's, no matter what variables are experimentally matched or eliminated. Such means as may be possible to reduce one, two, or n interaction(s) could also induce factors that interfere with drawing useful generalizations from a study.

Shoresman suggests a change in orientation towards research in curriculum which has particular relevance to the present study.

> ... it is recommended that we shift our research emphasis from attempting to place given concepts at specific conventional grade levels to deriving, by experimentation, content gradients which are capable of serving as guidelines for the development of sequences of learning experiences. (Shoresman, 1964, p. 79)

The design of the present investigation seems to approach Shoresman's recommendation. The variables in the study include IQ, sex, two broad grade categories, and four levels or "gradients" in a cognitive hierarchy from which instructional episodes were derived. Details of the hierarchy are explained in chapter no. 3.

Summary

After approximately 40 years in vintage, recommendations for articulated K-12 science curricula, and studies in developmental psychology have converged in a contemporary search for viable learning experiences in elementary science.

The knowledge explosion has induced an increasingly concerned search for a science curriculum that will serve young learners now and in the forseeable future by providing them with relatively stable mental paradigms upon which to base a developing awareness of scientific thought and enterprise. It is submitted that the search will be met by those who are investigating the conceptual schemes of science approach to a curriculum in elementary science.

The justification for curriculum research is grounded in results which have both general and operational applicability. To meet these criteria certain design features should be incorporated. These include: basing the content on levels of a cognitive hierarchy that have correspondence to levels of intellectual development in children and presentation of the lessons by the regular teacher, not the investigator or a specialist.

The conceptual scheme of the planetary atomic model, though supplanted in advanced studies, retains utility in description and prediction of a wide range of common physical-chemical events. The one comprehensive study which used the theme of atomics for elementary children (Reid, 1952) reported on instruction that was centered on descriptive atomic technology. The material received multi-class treatment, and was taught by the children's own teachers. However, the feasibility ascribable to the planetary atomic model as an instructional paradigm was not investigated at differential levels of cognition.

If an investigation of a portion of a curriculum based on a conceptual scheme of science is to meet its claimed potential it should meet two tests: (1) the aforementioned criteria for general and operational curricular applicability and (2) provide means to assess pupil attainments in a specified hierarchy of cognitive complexity.

CHAPTER III

THE DESIGN OF THE INVESTIGATION

The purpose of the study reported here has been to organize certain classroom episodes about a conceptual scheme of science, the planetary atomic model, at designated levels of instruction and cognitive attainments and to investigate their feasibility for middle elementary and pre-secondary pupils. The report on the design of the study parallels the five items below that summarize the sequence encompassing the experiment.

1. The hypotheses, generated from the purpose of the study, were formulated.
2. The statistics for testing the hypotheses were specified.
3. The instructional episodes, consisting of activities leading to and including the planetary atomic model, were written and subjected to jury validation procedures.
4. The instrument to measure cognitive attainments was written and subjected to jury validation. A pilot run in a 4th grade class yielded data for revision and re-validation of the instructional episodes and the test of cognitive attainments.
5. The instructional episodes were implemented in regular classrooms and data on cognitive attainments were collected.

1. The Hypotheses

A number of terms used in the hypotheses are explained in this section. Certain terms, which apply to the statistical techniques employed, are defined in section no. 2 of this chapter.

The need and justification for studies in elementary science which employ a major conceptual schemes curriculum was discussed earlier. The levels in the hierarchy of cognitive attainment designated for the present study have been derived from Bloom (1956) and Gagné (1966). The two levels are factual-conceptual and inferential.

It was recognized that the more complex level of the cognitive hierarchy may include less complex ones. Therefore, to discriminate more clearly between the two main levels of the hierarchy, two sequences of background episodes were developed, one for factual-conceptual and one for inferential. The background episodes were designed to give pupils certain experiences as a prelude to the main body of content on the planetary atomic model (PAM). The background experiences involved comparing, measuring, predicting, hypothesizing and evaluating the nature of certain physical events which cannot be seen or manipulated readily. Thus, each instructional episode and its measurement(s) was labeled as to cognitive level in one of the

four following ways: (1) Factual-conceptual, background for presentation of the PAM; (2) Factual-conceptual, pertaining to the PAM; (3) Inferential, background for presentation of the PAM; or (4) Inferential, pertaining to the PAM.

It is posited that evidence for a theory which underlies a particular cognitive instructional hierarchy is obtained in operational classroom experiences. In the present study, some estimates of the correspondence between hierarchical theory and practice may emanate from one or more of the following events:

1. Prior to instruction, the hierarchy is accepted as relevant by an expert panel of jurors;
2. After instruction, measurement indicates that success on a less complex level of the hierarchy is matched by success on the next most complex level;
3. After instruction, measurement indicates that success on a less complex level of the hierarchy does <u>not</u> yield success on the next most complex level;
4. After instruction, measurement indicates that significant success on a more complex level of the hierarchy is not preceded by as great a success at the less complex level. Such an event could mean that the more complex level re-included aspects of the less complex level and, therefore, provided successful reinforcement;

5. After instruction, measurement indicates that lack of success on a level devoted to background experiences in the hierarchy is also matched by a lack of success on the associated level which pertains to the main body of content, e.g., the PAM.

The anticipated hierarchy in which an aspect of curriculum is internalized by a pupil may be confounded by processes of teaching and/or differential mental pathways of individual pupils. For example, a concept or an inference may be imparted and learned as a fact. Therefore, to translate theoretical levels of thought complexity into curricular goals which have precise operational correspondence within pupils in regular classroom situations appears to be an abstruse undertaking. Interpretation of a pupil's thought processes while he is undergoing instruction requires some type of receptor (e.g., brain wave recorder, interview, responses to tests or programed texts or teaching machines). Such a receptor introduces a factor in the learning process which cannot be excluded from the outcome. Modern physics provides an analogy of this enigma in the uncertainty principle which holds that whatever is measured is changed by the act of measurement. It is submitted that a theoretical hierarchy of thought rendered to correspond to instructional goals by expert jury examination of instructional descriptions

provides a valid basis for experimental analysis with a concomitant reduction in risk of interaction between the subjects of measurement and how they are measured.

The levels of the cognitive instructional hierarchy referred to as factual-conceptual, and inferential were each given a specific interpretation from least to most complex, as follows:

Factual level of instruction and cognitive attainment; the objective of factual instruction is a change in behavior which has as its outcome knowledge of an event or phenomenon. Example: Bodies which have received electrostatically opposite charges tend to attract each other.

Conceptual level of instruction and cognitive attainment; the objective of conceptual instruction is a change in behavior which has as its outcome the internalizing of an idea or generalization that links facts together in terms of abstracted properties such as color, position, number (ordinal, cardinal), degree of change, type of change, etc. Example: Electrostatic effects are increased as the work which is done to produce the effect is increased.

Inferential level of instruction and cognitive attainment; the objective of inferential instruction is a change in behavior which has as its goal the ability to arrive at a seemingly incontrovertible outcome from mental models, reasoning, partial evidence and relevant facts, without a complete basis in physical proof. Example: The concept of multiprotonic nuclei is seemingly incongruous because of the known effect of electrostatic repulsion exerted by protons on one another. To account for the evidence of relatively small, dense atomic nuclei containing positive charges, it must be inferred that such charges are bound together by special "forces."

Middle Elementary and Pre-secondary Grade Categories

For curriculum innovation to have general relevance to classroom instruction of children it is desirable that the classroom milieu be preserved so that variables due to experimental intrusions may be kept to a minimum. In the present study the classes were kept intact. Schools are generally organized by child age level, but it may not be a reliable criterion of scholastic level from school to school. Therefore, for purposes of drawing more general inferences from the data, two broad categories of grade level

were formed for analysis, namely, middle elementary (grade 3 and grade 4) and pre-secondary (grade 5 and grade 6).

The middle elementary grade category consisted of two 3rd grade and two 4th grade classes with a reference or "control" class and an experimental or treatment class at each grade level; the pre-secondary grade category was organized in a like fashion. Each class was essentially self-contained and had been together for over a semester when the experiment was introduced. A total of 236 children in eight classes were in the sample. Ultimately the data from 226 children were used for statistical analysis. The eight classes were considered to have similar scholastic ability by the school staff, in that normal achievement could be expected based on past experiences.

The four classes designated as experimental received the new treatment from their own teachers. The teachers received special training from the investigator. Reference classes pursued their regular science program. The teachers, experimental and reference, were drawn from a pool of volunteers and matched by the principal for experience and training.

A more detailed description of the experimental setting is presented in section no. 5 of this chapter.

Measures of Mental Ability

Indices derived from nation-wide standardized tests were used in the present study to appraise the mental ability or scholastic aptitude of pupils. Every effort was made to obtain recent measures in such a way that school routines would not be unduly compromised, nor would the children be subjected to boredom and fatigue. Therefore, school records were employed where available, and special testing provided only for those pupils (approx. 6%) for whom there was no usable record.

In September, 1968 the pilot class, a fourth grade in the Campus School, State University College, Cortland, New York, was given the Otis-Lennon Mental Ability Test (1967). In the experiment at the Moravia, New York elementary school, the third and fifth grade classes were given the Lorge-Thorndike Intelligence Test (1966) in March, 1969 as part of the school's regular testing cycle. The fourth grade classes had taken the Lorge-Thorndike in spring, 1968. The sixth graders had taken the California Test of Mental Maturity in spring, 1968 when they were fifth graders. At the time of the experiment in spring, 1969, pupils who had no previous record were given the California Test of Mental Maturity (1963).

The intercorrelations of these three mental ability tests are fairly high (r = .6 to .7 and higher) from sample sizes that indicate high statistical significance. (California

Test of Mental Maturity, 1965, p. 26. also Lorge, et al., 1966, p. 26, also Otis, A. S. and Lennon, R. T., 1967, p. 38).

The scores on each of the tests are reported in terms of deviation IQ (DIQ), a standard score with a mean of 100 and a standard deviation of 16. Scores derived from the use of the tests, if normally distributed, are directly comparable with each other. Pinneau (1961) has compared the ratio IQ to the deviation IQ:

> In contrast to the conventional IQ is the deviation IQ which indicates the same relative standing at all ages. Consequently a subject's DIQ will not change unless he changes in the age group. (Pinneau, 1961, p. 29)

Chronbach (1960, 1963) has suggested that in some cases an index of a pupil's mental age is preferable to IQ. However, in dealing with mental age equivalent scores the publisher of the Otis-Lennon test argues that:

> One basic disadvantage... is the lack of equality in units throughout the scale. (Otis-Lennon, Manual, 1967, p. 16)

Therefore, it is held that a single derived score, the DIQ can be applied to summarizing performance at all levels of a test of mental ability. Anastasi has commented on the advantage of DIQ:

> ... if an SD close to 16 is chosen in reporting standard scores... the resulting numerical scores can be interpreted in the same way as Stanford-Binet's IQs.... [Educators] have learned what to expect from

> Individuals with IQs of 40, 70, 90, 130.... There are therefore certain practical advantages in the use of a derived scale which corresponds to the familiar distribution of the Stanford-Binet IQ. (Anastasi, 1954, pp. 85, 86)

The two sets of DIQs available for the study were combined for the experimental groups by sex for grade level and objective of instruction. The combining was achieved by T-scaling which yields a normalized distribution and standard scores with a mean of 50 and standard deviation of 10. T-scores of IQs for the reference ("control") groups were not employed directly in testing hypotheses. However, school authorities indicated that all classes used in the investigation were grouped at the beginning of the school year on the basis of similar scholastic achievement; comparisons between reference and experimental categories were therefore justified.

Garrett has stated the general case for T-scaling measures of mental ability:

> T scaling forces normality upon scores of a frequency distribution and is unwarranted if the distribution of the trait in the <u>population</u> [italicized in original] is not normal. For the distributions of most mental abilities in the population, however, normality is a reasonable— and is often the only feasible— assumption. (Garrett, 1966, p. 318)

Conversion tables of IQs to T-scores are presented in Appendix D.

Significant Attainment and Significant Correlation

For the experimental run of this study the .01 level of significance was chosen. Compared to $\alpha = .05$, for example, the risk of "accepting" a false hypothesis at $\alpha = .01$ is increased. However, because this is an investigation of curriculum feasibility, and given the size and nature of the sample, it is submitted that those who may peruse the findings for possible school implementation would seek assurance that an hypothesis had at least a one in one hundred probability of false rejection.

The phrases "significant attainment" and "significant difference.....in attainments" appear respectively in hypotheses 1a through 4b, and 5a through 8b. In hypotheses 1a through 4b the variables to be assessed are pre and post instructional test scores for experimental and reference ("control") classes by grade level and instructional objectives. In hypotheses 5a through 8b the variables are the post instructional test scores by sex for each grade level and instructional objective. For evaluating hypotheses 1a through 8b the statistical technique of analysis of variance was employed.

The phrase "significant correlation" appears in hypotheses 9a through 16b. The variables in these hypotheses are

IQ T-scaled, and post-instructional test scores by instructional objective, sex and grade level. For evaluating hypotheses 9a through 16b the statistical technique of Pearson product-moment correlation and the t test for significance from zero of the correlation coefficient in the population (rho) were employed.

The rationale for the use of these statistical techniques is discussed in the second section of the chapter.

The Hypotheses

Hypothesis 1a.

Middle elementary pupils make no significant attainment on the factual-conceptual goal of instruction from a sequence of classroom cognitive experiences which are background for presentation of the planetary atomic model.

Hypothesis 1b.

Middle elementary pupils make no significant attainment on the factual-conceptual goal of instruction from a sequence of classroom cognitive experiences which pertain to the planetary atomic model.

Hypothesis 2a.

Middle elementary pupils make no significant attainment on the inferential goal of instruction from a sequence of classroom cognitive experiences which are background for presentation of the planetary atomic model.

Hypothesis 2b.

Middle elementary pupils make no significant attainment on the inferential goal of instruction from a sequence of classroom cognitive experiences which pertain to the planetary atomic model.

Hypothesis 3a.

Pre-secondary pupils make no significant attainment on the factual-conceptual goal of instruction from a sequence of classroom cognitive experiences which are background for presentation of the planetary atomic model.

Hypothesis 3b.

Pre-secondary pupils make no significant attainment on the factual-conceptual goal of instruction from a sequence of classroom cognitive experiences which pertain to the planetary atomic model.

Hypothesis 4a.

Pre-secondary pupils make no significant attainment on the inferential goal of instruction from a sequence of classroom cognitive experiences which are background for presentation of the planetary atomic model.

Hypothesis 4b.

Pre-secondary pupils make no significant attainment on the inferential goal of instruction from a sequence of classroom cognitive experiences which pertain to the planetary atomic model.

Hypothesis 5a.

There is no significant difference attributable to sex in attainment of middle elementary pupils on the factual-conceptual goal of instruction from a sequence of classroom cognitive experiences which are background for presentation of the planetary atomic model.

Hypothesis 5b.

There is no significant difference attributable to sex in attainment of middle elementary pupils on the factual-conceptual goal of instruction from a sequence of classroom cognitive experiences which pertain to the planetary atomic model.

Hypothesis 6a.

There is no significant difference attributable to sex in attainment of middle elementary pupils on the inferential goal of instruction from a sequence of classroom cognitive experiences which are background for presentation of the planetary atomic model.

Hypothesis 6b.

There is no significant difference attributable to sex in attainment of middle elementary pupils on the inferential goal of instruction from a sequence of classroom cognitive experiences which pertain to the planetary atomic model.

Hypothesis 7a.

There is no significant difference attributable to sex in attainment of pre-secondary pupils on the factual-conceptual goal of instruction from a sequence of classroom cognitive experiences which are background for presentation of the planetary atomic model.

Hypothesis 7b.

There is no significant difference attributable to sex in attainment of pre-secondary pupils on the factual-conceptual goal of instruction from a sequence of classroom cognitive experiences which pertain to the planetary atomic model.

Hypothesis 8a.

There is no significant difference attributable to sex in attainment of pre-secondary pupils on the inferential goal of instruction from a sequence of classroom cognitive experiences which are background for presentation of the planetary atomic model.

Hypothesis 8b.

There is no significant difference attributable to sex in attainment of pre-secondary pupils on the inferential goal of instruction from a sequence of classroom cognitive experiences which pertain to the planetary atomic model.

Hypothesis 9a.

There is no significant correlation between a measure of mental ability of middle elementary boys and their attainment on the factual-conceptual goal of instruction from a sequence of classroom cognitive experiences which are background for presentation of the planetary atomic model.

Hypothesis 9b.

There is no significant correlation between a measure of mental ability of middle elementary boys and their attainment on the factual-conceptual goal of instruction from a sequence of classroom cognitive experiences which pertain to the planetary atomic model.

Hypothesis 10a.

There is no significant correlation between a measure of mental ability of middle elementary girls and their attainment on the factual-conceptual goal of instruction from a sequence of classroom cognitive experiences which are background for presentation of the planetary atomic model.

Hypothesis 10b.

There is no significant correlation between a measure of mental ability of middle elementary girls and their attainment on the factual-conceptual goal of instruction from a sequence of classroom cognitive experiences which pertain to the planetary atomic model.

Hypothesis 11a.

There is no significant correlation between a measure of mental ability of middle elementary boys and their attainment on the inferential goal of instruction from a sequence of classroom cognitive experiences which are background for presentation of the planetary atomic model.

Hypothesis 11b.

There is no significant correlation between a measure of mental ability of middle elementary boys and their attainment on the inferential goal of instruction from a sequence of classroom cognitive experiences which pertain to the planetary atomic model.

Hypothesis 12a.

There is no significant correlation between a measure of mental ability of middle elementary girls and their attainment on the inferential goal of instruction from a sequence of classroom cognitive experiences which are background for presentation of the planetary atomic model.

Hypothesis 12b.

There is no significant correlation between a measure of mental ability of middle elementary girls and their attainment on the inferential goal of instruction from a sequence of classroom cognitive experiences which pertain to the planetary atomic model.

Hypothesis 13a.

There is no significant correlation between a measure of mental ability of pre-secondary boys and their attainment on the factual-conceptual goal of instruction from a sequence of classroom cognitive experiences which are background for presentation of the planetary atomic model.

Hypothesis 13b.

There is no significant correlation between a measure of mental ability of pre-secondary boys and their attainment on the factual-conceptual goal of instruction from a sequence of classroom cognitive experiences which pertain to the planetary atomic model.

Hypothesis 14a.

There is no significant correlation between a measure of mental ability of pre-secondary girls and their attainment on the factual-conceptual goal of instruction from a sequence of classroom cognitive experiences which are background for presentation of the planetary atomic model.

Hypothesis 14b.

There is no significant correlation between a measure of mental ability of pre-secondary girls and their attainment on the factual-conceptual goal of instruction from a sequence of classroom cognitive experiences which pertain to the planetary atomic model.

Hypothesis 15a.

There is no significant correlation between a measure of mental ability of pre-secondary boys and their attainment on the inferential goal of instruction from a sequence of classroom cognitive experiences which are background for presentation of the planetary atomic model.

Hypothesis 15b.

There is no significant correlation between a measure of mental ability of pre-secondary boys and their attainment on the inferential goal of instruction from a sequence of classroom cognitive experiences which pertain to the planetary atomic model.

Hypothesis 16a.

There is no significant correlation between a measure of mental ability of pre-secondary girls and their attainment on the inferential goal of instruction from a sequence of classroom cognitive experiences which are background for presentation of the planetary atomic model.

Hypothesis 16b.

There is no significant correlation between a measure of mental ability of pre-secondary girls and their attainment on the inferential goal of instruction from a sequence of classroom cognitive experiences which pertain to the planetary atomic model.

2. The Statistics for Testing the Hypotheses

The statistical deployment is presented in Tables I and II.

Key to Tables:

I Q	represents	deviation IQ
M.E.	represents	the middle elementary level classes;
P.S.	represents	the pre-secondary level classes;
X	represents	the experimental classes;
R	represents	the reference classes;*
Fact.-Conc.	represents	the instructional objective of factual-conceptual cognitive attainments;
Infer.	represents	the instructional objective of inferential cognitive attainments;
Background	represents	test items which measure attainment of instructional objectives from a sequence of classroom cognitive experiences that provide background for presentation of the planetary atomic model.
P A M	represents	test items which measure attainment of instructional objectives from a sequence of classroom cognitive experiences pertaining to the planetary atomic model.

*similar to control classes, except no comparative treatment is specifically applied

TABLE I

Deployment of Statistics for Testing Hypotheses 1a through 8b.

Hypotheses 1 or 3*

a) M.E. or P.S. Both Pre and Post Fact.-Conc.

X	R
Background	Background

analysis of variance

b) M.E. or P.S. Both Pre and Post Fact.-Cono.

X	R
PAM	PAM

analysis of variance

Hypotheses 2 or 4*

a) M.E. or P.S. Both Pre and Post Infer.

X	R
Background	Background

analysis of variance

b) M.E. or P.S. Both Pre and Post Infer.

X	R
PAM	PAM

analysis of variance

*Hyp. 1, 2 = Middle Elementary
Hyp. 3, 4 = Pre-Secondary

(continued)

TABLE I (concluded)

Hypotheses 5 or 7*

a) $M.E._x$ or $P.S._x$ Post Fact.-Conc.

Boys Background	Girls Background

analysis of variance

b) $M.E._x$ or $P.S._x$ Post Fact.-Conc.

Boys PAM	Girls PAM

analysis of variance

Hypotheses 6 or 8*

a) $M.E._x$ or $P.S._x$ Post Infer.

Boys Background	Girls Background

analysis of variance

$M.E._x$ or $P.S._x$ Post Infer.

Boys PAM	Girls PAM

analysis of variance

*Hyp. 5, 6 = Middle Elementary
Hyp. 7, 8 = Pre-Secondary

Variance analysis provides a method for testing hypotheses concerning means of two or more populations. One-way analysis of variance was used to test the significance of pre and post instructional attainments of experimental and reference classes by instructional objective and grade level. It was also used to test significance of post-instructional attainments of experimental classes by sex for instructional objectives. A general formula for analysis of variance follows:

$$\Sigma_j \Sigma_i (Y_{ij} - M)^2 = \Sigma_j \Sigma_i (Y_{ij} - M_j)^2 + \Sigma n_j (M_j - M)^2$$

Total Sum of Squares	=	Sum of Squares, Within (Error)	+	Sum of Squares, Between (Treatment)

where j represents a treatment population;

i represents an observation;

Y_{ij} represents any score;

M represents mean of all individuals in all treatments;

and M_j represents mean of a sample given a particular treatment j.

The variance ratio, F, is derived from the sums of squares of treatment and error terms, each divided by an appropriate number of degrees of freedom.

TABLE II

Deployment of Statistics for Testing Hypotheses 9a through 16b

Hypotheses 9 or 10*

a) M.E.$_X$ boys or girls

Fact.-Cono.

I Q	Post-test Background

P.M. correlation and t test for rho

b) M.E.$_X$ boys or girls

Fact.-Cono.

I Q	Post-test PAM

P.M. correlation and t test for rho

Hypotheses 11 or 12*

a) M.E.$_X$ boys or girls

Infer.

I Q	Post-test Background

P.M. correlation and t test for rho

b) M.E.$_X$ boys or girls

Infer.

I Q	Post-test PAM

P.M. correlation and t test for rho

*Hyp. 9, 11 = boys
Hyp. 10, 12 = girls

(continued)

TABLE II(concluded)

Hypotheses 13 or 14*

a) $P.S._x$ boys or girls
Fact.-Conc.

I Q	Post-test Background

P.M. correlation
and
t test for rho

b) $P.S._x$ boys or girls
Fact.-Conc.

I Q	Post-test PAM

P.M. correlation
and
t test for rho

Hypotheses 15 or 16*

a) $P.S._x$ boys or girls
Infer.

I Q	Post-test Background

P.M. correlation
and
t test for rho

b) $P.S._x$ boys or girls
Infer.

I Q	Post-test PAM

P.M. correlation
and
t test for rho

*Hyp. 13, 15 = Boys
Hyp. 14, 16 = Girls

A correlation index, the Pearson product-moment coefficient and its significance from a population coefficient of zero was employed for comparing IQs with post-instructional attainments by sex for each objective by grade level.

A general formula for product-moment correlation is written as follows:

$$r = \frac{\Sigma xy}{Ns_x s_y}$$

where x represents deviation measures from the mean of the X variable ;

y represents deviation measures from the mean of the Y variable ;

s_x is the standard deviation of the X variable;

s_y is the standard deviation of the Y variable;

N represents the number of respondents from whom bivariate measurements were obtained;

and Σxy represents the sum of the products of all the X and Y deviations, all such products summed algebraically.

In the actual calculations a raw score formula was employed.

The hypothesis of a population correlation coefficient of zero was tested for significance by the formula:

$$t = \frac{r_{xy}\sqrt{N-2}}{\sqrt{1-r_{xy}^2}}$$

where r_{xy} represents the correlation coefficient;

N represents the number of respondents from whom bivariate measurements were obtained;

and the t ratio is for N-2 degrees of freedom.

There is the possibility that measured gains could, in part, be attributed to maturation or accrual of casual information. To assess such an inference among reference classes for differences on pre and post instructional attainments, a formula for evaluating the significance of the difference between related means was employed, as follows:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\frac{1}{N}\sqrt{\frac{\Sigma D^2 - (\Sigma D)^2}{N-1}}}$$

where X_1 and X_2 represent, respectively, post and pre instructional means;

$\sum D$ represents sum of differences of individual scores;

$\sum D^2$ represents sum of squares of differences of individual scores;

N represents the number of comparisons;

and the t ratio is for n - 1 degrees of freedom.

The calculations for analysis of variance and Pearson correlation were rendered by computer programs. The programs are identified in chapter no. 4.

3. The Instructional Episodes

A sequence of instructional episodes was developed by the investigator to involve middle elementary and pre-secondary pupils in classroom activities which have as their designated objectives factual-conceptual or inferential outcomes (or a combination of these) concerning a simplified planetary atomic model and its application to selected physical phenomena. Some of the instructional episodes were designed as background for presentation of other

episodes which pertain directly to cognitive experiences on the planetary atomic model (PAM). Thus, each episode had one of four possible designations in the hierarchy of cognitive attainments employed for this study: (1) factual-conceptual (background); (2) factual-conceptual (PAM); (3) inferential (background); or (4) inferential (PAM).

The episodes consisted of learning activities that were compiled and modified from a number of sources which included curriculum handbooks, commercial sourcebooks, and even college textbooks. Each episode was prefaced with an objective stated in behavioral terms. Cureton, et al.. (1951) have written on the need for behavioral objectives as a necessary adjunct to the creation of educational experiences that have the quality of intrinsic validity. They state:

> We can define any purpose for education or measurement that we please. If there is widespread agreement as to the worthiness of the purpose, it may be labeled an educational aim or goal. This does not mean that it will become at once a useful ultimate criterion for the validation of tests or for the improvement of the educational program. A useful ultimate criterion demands much more than the statement

> in abstract terms of a worthy purpose. The statement must imply unambiguously or specify explicitly an area of behavior which is operationally definable, operationally observable, and operationally scorable. [italicized in original] (Cureton, et al., In Lindquist, 1951, p. 650)

A jury of validators for the instructional episodes and the measurement instrument were drawn from a pool of six science educators and one elementary reading specialist. The science educators, taken collectively, have had teaching experiences ranging from kindergarten through graduate level. Of the science educators, four have taught college courses in chemistry or physics, and all but one have taught courses in science education. The doctorate is held by the reading specialist and three of the science educators. All of the remaining jurors have extensive formal academic credentials in science beyond the master's degree.

Jurors with a background in science education were asked to consider two general aspects of each written episode: (1) the content accuracy of the activities or activity; (2) the extent of their agreement with the stated objective(s).

The directions to the jurors appear in Appendix A. An objective was accepted if a majority of the jurors agreed with the original designation assigned by the investigator. When two or more jurors disagreed with the investigator, dissenting commentaries (solicited as an option) were sometimes useful in reassigning the objective, and/or recasting an activity. In a number of cases, an acceptance majority was obtained by combining two or more objectives. The possibility for such combinations was provided for in the jurors' rating sheet. However, in the early stages of validation combining of objectives was so prevalent among jurors that it was decided to designate no more than two levels of instructional and cognitive objectives for the purpose of statistical analysis: (1) if an episode, either background or PAM, and its measurement was designated factual, or conceptual, or factual-conceptual, it was placed in a level of instructional objective called factual-conceptual, and (2) if an episode, either background or PAM and its measurement was designated inferential, or conceptual-inferential, or factual-conceptual-inferential, it was placed in a level of instructional objectives called inferential. These two levels of objectives (1) factual-conceptual, and (2) inferential, for each of background and PAM episodes, are designated as such throughout the remainder of the dissertation.

Nearly 40% of the original collection of instructional episodes was deleted via the process described. The remaining ones were modified or largely re-written to meet suggestions and criticisms, and to provide a logical and psychological continuity for presentation to the pilot class and, ultimately, the experimental classes.

The episodes were designed for presentation in a span of not more than 30 daily periods of 30 to 45 minutes each. The variability in time provided for inevitable interruptions in classroom schedules. Also, a stringent schedule could have resulted in the building of tensions and deprecative attitudes by pupils and teachers in situations where ideas and materials require periods of intense concentration.

The teaching method of discussion was emphasized in the episodes. Discussion, broadly defined includes the technique of lecture-discussion, demonstration-discussion, and small group and individual work followed by discussion(s). Short increments of reinforcement activities were included.

Compared to any other instructional method, aside from tutorial, the discussion method offers possibly the greatest opportunity for pupil-teacher-class interaction per unit of time. It permits classwide sharing of mental formulation and tests of hypotheses, the drawing of tentative conclusions, and thus enhances the probability that pupils participate in, and internalize the content. Gagné (1965) has commented on the efficacy of the discussion method:

> It is said that education should be concerned not simply with the acquisition of knowledge, but more importantly with the use and generalization of knowledge in novel situations... it is evident that knowledge transfer cannot occur if the knowledge itself has not been initially transferred... beyond this, there is an important question of what conditions of instruction are required to encourage generalization of knowledge... the instructional mode of organized group discussion [italicized in original] is one that appears to be well designed to accomplish this function. When properly led, such discussion not only stimulates the production of new extensions of knowledge by students, but also provides a convenient means of critical evaluation and discrimination of these ideas. (Gagné, 1965, pp. 27, 28)

Several significant techniques and tools of teaching were omitted because of the added variables which they introduce, and also because of time limitations; these include films, filmstrips, library reports, and projects. In neither of the grade placement studies cited earlier, Oxendine, (1953) and Reid, (1952), was method tested as a variable. Oxendine used only one demonstration followed by the opportunity for a brief discussion. Reid's plans implied lecture-recitation and included the use of a selected piece of popular literature on the topic. Oxendine taught the lesson to each of 15 experimental classes. Reid's lessons were taught by the regular classroom teacher. Though the method of instruction has been arbitrarily selected by the investigator, he submits that it is not markedly unlike that which is regularly employed by successful classroom teachers.

The sequence of instructional episodes is presented in Appendix C.

4. The Measurement Instrument

The investigator's search for a prepared instrument which would measure the attainment of the stated objectives of instruction for the study was fruitless. Therefore, it was necessary to prepare an instrument and process it for content validity and an estimate of reliability.

H. L. Thorndike, et al., (1951) have commented on the nature of estimating validity of achievement tests:

> In the evaluation of achievement test scores, reliability data may often appear to be the most basic statistical data with regard to the test. This is the case because in tests of this sort validity tends to be established by other than statistical means. Validity becomes a question of appropriateness of content to the course subject matter and appropriateness of form of test to the course objectives. (Thorndike, R. L., et al. In Lindquist, 1951, pp. 607, 608)

Each instructional episode was labeled by the investigator and subsequently jury validated as to objective, namely, factual-conceptual (background), factual conceptual (PAM), inferential (background), or inferential (PAM). Each episode had attached to it at least one four-option multiple choice examination item. The examination items were derived from the instructional episodes and each item carried the same objective(s) as its source episode. The collection of examination items constituted the measuring instrument, given as a pre-instructional and post-instructional test. Pass or

fail of an item or items was taken as definitive measure of a pupil's achievement of the objective(s) of the associated instructional episode. The same items were used for both test sessions, but the items were re-arranged in a partial random order for the pre-instructional test. The arrangement of the post-instructional test items followed the sequence of instruction.

Every word in the examination was checked against the Dale and Chall (1948) list of familiar words for fourth and fifth grade children. All words used in the test but not included in the aforementioned word list were listed as new words in the written instructional episodes and treated as such in the classroom activities.

The pilot version of the test was subjected to a jury analysis. Gulliksen (1950) has noted an important aspect in the selection-rejection procedures for achievement tests. He states:

> The judgment of the subject matter expert must always play an important part in the selection and rejection of items for an achievement test. If the item analysis results show that a given item should be used and the expert finds that the item is incorrect, that item must be revised. If the item analysis results show that an item should be deleted, and the subject matter expert feels that essential knowledge is being tested in the item, then attempts must be made to discover the flaw in item construction and revise the item so that it will satisfy both the item analysis criteria and the judgment of the subject matter specialist. ... In an achievement test, the goal should be

> to obtain items that are satisfactory from the viewpoint of both the item analysis results and the subject matter specialist. In order to do this, it may be necessary to revise the item, to revise the criterion against which the item is validated, to revise the methods of teaching, or to revise the content of the course. (Gulliksen, 1950, p. 365)

The pilot form of the test was subjected to a sequence of juror-validation as follows:

1. The science content of each item was subjected to analysis and the phraseology, aside from the specialized science vocabulary, was juror-evaluated for appropriateness for middle elementary pupils;

2. The validation process outlined in no. 1 led to the revision of a number of items and the deletion of several. Each instructional episode and its associated test item(s) was then subjected to juror scrutiny to decide whether or not the stated behavioral objective of the instruction was, in effect, measured by the multiple choice test item(s) associated with it. On borderline judgments jurors were directed to vote <u>against</u> acceptance of an item. Also, at this stage of validation the reading specialist, mentioned earlier, examined the reading level of the entire test and he found it acceptable.

The directions to the jurors for both stages are presented in Appendix A.

From the original pool of examination items, nearly 45% were discarded. The remaining ones were either accepted or revised on the basis of juror reactions. In the pilot run, 57 examination items were included. In the final form of the examination, 48 items were included. The final version appears in Appendix E.

The pilot run was initiated September, 1968 in a fourth grade class in the campus school of State University College, Cortland, New York. The regular instructor, Miss Ann Werder, carried out nearly all phases of instruction. She is not a science specialist. Miss Werder is highly regarded by the staff, children and their parents. She has had wide experience in college teaching and teaching in a campus school. Her academic credentials, other than in science, are well beyond the master's level.

Contrary to common belief, the Cortland campus school does not have a preponderance of faculty children. In the pilot class over two-thirds of the 21 children were from non-faculty homes.

The Otis-Lenom Mental Ability Test (1967) was administered by the guidance counselor prior to the inception of the pilot run. Class indices, reported in deviation IQ units, are as follows: Mean = 103; standard deviation = 17.361; range = 76-135.

The investigator regularly observed the pilot run from a room equipped with one-way glass. He briefly assisted during

several difficult sessions. Such assistance is a natural event in the Cortland campus school because there is much demonstration and participation for the benefit of the college students. In the experimental run, to be described, the investigator's assistance was limited to training the teachers.

Data obtained from the pilot class are presented in Appendix B. The pilot run did not include a reference or control class because a comparably-led fourth grade class was not available.

An item analysis of the post-instructional test was performed after a method described by Garrett (1966) and Tate (1964). In the item analysis a "difficulty index" and an "index of item discrimination" (sometimes called an index of item validity) were calculated for each item used in the pilot run. Garrett (1966) has referred to the difficulty index in a general application which resembles that of the present study:

> ... when item correlations are high (as is true in most educational achievement tests) and the talent range wide (over several grades) difficulty indices may range from high to low... 50% of the items might have difficulty indices between .25 and .75 (Garrett, 1966, p. 364)

The proportion passing an item is an index of item difficulty; if 50% of a group pass an item, that item has maximum variance, that is, it spreads the examinees out more than an easier item or a more difficult item. Garrett (1966) provides a rule for selection of items based on their difficulty index. He suggests that:

> Other things being equal, items of moderate difficulty (40% - 50% - 60% passing) are to be preferred to those which are much easier or much harder. (Garrett, 1966, p. 363)

An index of item discrimination was also calculated. Items that discriminate are those that correlate positively with the total scores. Tate (1964) has pointed out that:

> Whenever we can correlate... the response to a single item with some large measure of performance on an instrument, we can obtain an index of the discriminative powers or consistency of the item. The deletion of inconsistent items will generally improve the instrument. (Tate, 1964, p. 209)

The index of item discrimination was calculated for each item after Flanagan's method of approximating the biserial coefficient (r_b) using 27% of the group scoring highest on the whole test and 27% of the group scoring the lowest.

Tate (1964) has made reference to the issue of test validity in connection with the index of discrimination. He states:

> ... the higher the validity coefficient of the items [item discrimination index] the greater the validity or predictive value of the test. The validity of tests usually can be improved to some extent through item analysis; however, it is common experience that items showing substantial validity are hard to find. (Tate, 1964, p. 211, 212)

Following the pilot run, the top one-third of each sex group was interviewed to obtain respondents' perceptions of items which were answered incorrectly, or which they wanted to discuss. The results of the interviews were used to eliminate some questions, recast some activities, and re-structure some questions based upon certain criteria for selection of examination items; the criteria were the aforementioned ones outlined by Garrett (1966) and Tate (1964) for the indices of difficulty and discrimination. A summary of the item analysis is presented in Appendix B. A fourth panel adjudication was conducted to appraise the validity of the pilot-induced modifications vis-a-vis the revised instructional episodes and the measurement instrument. Directions to jurors appear in Appendix A.

It is submitted that a sequence of analysis-interview revise and/or reject and jury re-evaluation is a necessary concomitant to improving the intrinsic validity of the instrument. The content or formal validity

of the test items has been estimated (and described earlier) by a sequence advocated by Tate (1964). He has asserted that:

> A test item may be said to be formally valid when it is consistent with content that has been taught, specifications drawn up in advance, the opinions of experts and so forth. (Tate, 1964, p. 211)

An estimate of the reliability of the examination was made by the internal consistency method. Walker and Lev (1953) have noted that there are a great many ways of subdividing a singly-administered test and warn of the consequent indeterminacy of the estimate of the reliability coefficient obtained by correlating scores on the basis of split halves. They recommend a formula by Kuder and Richardson which provides "a kind of average" of the various reliability coefficients that could be obtained from all the ways of subdividing a given set of test items. (Walker & Lev, 1953, p. 312)

The Kuder-Richardson formula for estimating reliability of a test is:

$$r_{xx} = \frac{m}{m-1}\left(1 - \frac{\sum(Np_1)\,(Nq_1)}{N(N-1)\,s_x^2}\right)$$

where N represents the number of individuals taking the test;

m represents the number of items in the test;

p_i represents the proportion of individuals answering i^{th} item correctly;

Np_i represents the number of individuals answering the i^{th} item correctly;

$1-p_i$ equals q_i which represents the proportion of individuals answering a designated item correctly;

Nq_i represents the number of individuals not answering the i^{th} item correctly;

s^2 represents the variance of the test scores of the N individuals, each score being the number of items answered correctly by the individual;

and r_{xx} represents coefficient of correlation for split-halves estimate of reliability.

A coefficient of estimated reliability obtained by a split-halves method is termed a coefficient of internal consistency. The estimated reliability coefficient for the pilot run, and for the experimental run is presented in Table XLIV.

5. Implementation of the Instructional Episodes and Measurement of Attainments

The classrooms for the experimental run were volunteered from the Moravia, New York elementary school. Moravia, with a population of 1500, is in the southern portion of Cayuga County. The picturesque locale is several miles south of Owasco Lake, one of the smaller of the famed Finger Lakes. The vast majority of the 1800-2000 families that send children to the Moravia Central Schools live in rural settings outside the town. The school is the center of community life.

Pervasive in the economic life of the area is agriculture and associated services. Considerable employment is also derived from governmental agencies and from factories in three nearby small cities and Syracuse. Poverty, borderline and extreme, is not insignificant in the area. Community fathers are attempting to enhance the area's reputation as a tourist attraction with private investments in recreation facilities. Ethnically predominant are white Protestants of Anglo-Saxon origins.

The drop-out rate of the school system is less than the state average. More than half of the more than 100 students in each of the recent senior classes started school in Moravia kindergartens. One-third to one-half of the graduates go on to some type of higher training or formal education.

The principal matched the teachers by experience and training for reference (R) and experimental (X) classes from a larger group of volunteer teachers. The deployment is shown in Table III. None of the X or R teachers had credentials in graduate level courses, workshops nor institutes in science or science teaching methods.

TABLE III

Deployment and Credentials of Experimental (X) and Reference (R) Teachers

Grade Level	X or R	Teacher	Tenure	Degree and/or N. Y. State Certification	Experience in Years
3rd	X_{ME}*	Mrs. MacKay	No	BA Permanent	5
3rd	R_{ME}	Miss Nedrow	No	BS Provisional	1st
4th	X_{ME}	Mrs. Fenstermacher	No	BS Provisional	1.5
4th	R_{ME}	Mr. Boedicker	No	BS Provisional	1st
5th	X_{PS}*	Mrs. Mosher	Yes	Permanent Certificate	30
5th	R_{PS}	Mrs. Hartnett	Yes	Permanent Certificate	30
6th	X_{PS}	Mr. Ward	No	BS Provisional	5
6th	R_{PS}	Mr. Berlew	No	BS Provisional	3

*Middle Elementary (ME) or Pre-Secondary (PS)

Each of the grade level categories, namely, middle elementary and pre-secondary, was assigned two experimental and two reference classes for purposes of statistical analysis.

The teachers of the experimental groups received training to teach the instructional episodes and the teachers of the reference classes received no training. The reference classes continued with their regular science program. The purpose of the reference classes was two-fold: (1) to make an approach to randomization of class selection, and (2) to serve as a check on content information that might be acquired by volunteer classes which did not receive instruction, but were subjected to pre and post instructional testing.

All classes were essentially self-contained. Grouping by scholastic ability is practiced, and the administrative staff and teachers considered the differences among these classes as negligible. The classes were composed of pupils who had demonstrated in earlier school experiences that they could be expected to maintain normal achievement with their age peers. There were no accelerated classes in the school, but there were classes for children with problems that hindered their school progress. None of the latter classes were included in the study.

In a limited sense, group homogeneity in scholastic ability may be estimated from a raw fusion of the several

sets of DIQs secured for statistical analysis (for evaluation of hypotheses 9a through 16b, DIQs were converted to T-scores). Approximately 60% of each grade level category, middle elementary and pre-secondary experimental and reference classes, had DIQs in the 90-110 range. The highest DIQ, 127, was from a reference class, and the lowest, 70, was from an experimental class.

The teachers of the experimental classes were trained by the investigator in three sessions, totaling nearly 12 hours. Part of the training was on school time and part on the teachers' time. A professional consultation fee was paid to the experimental teachers in consideration for their time spent in training and preparation for instruction. They were taught to lead discussions and perform simple demonstrations as described in the written instructional episodes.

Expenses for instructional materials were paid by the Finger Lakes Supplementary Educational Center, a Title III (Elementary and Secondary Education Act of 1965) agency of the U. S. Office of Education. No salary or stipend accrued to the investigator.

Of course, it was not possible to provide purely identical conditions for each classroom for instruction and testing. It is submitted that the uncontrolled variables were part of the natural differences (location, lighting, temperature, daily and special schedules, teachers' cycle

of enthusiasm, etc.) that are continually present among ongoing classrooms.

During the tenure of the experimental run, the investigator was present in the school for informal consultations with the teachers twice a week. All instruction was carried out by the regular classroom teacher.

The pre-instructional and post-instructional forms of the measurement instrument were administered to each class by its own teacher. The pre-instructional form was administered on March 4, 1969. Stragglers, approximately 4% of the total, were administered the test by the investigator on March 6, 1969. The post instructional form was administered on June 4, 1969. Stragglers, approximately 4% of the total, were administered the test by the investigator on June 6, 1969. Ultimately, the scores of 226 pupils were used in the study from an original enrollment of 236. The difference represents absentees from scheduled testing sessions on the dependent variables or the independent variable (IQ). Attendance was normal, except for the pre-secondary groups during the last few days of the experiment. An extended outdoor field trip, apparently without proper clothing, led to an unusual number of illnesses. Also, some of the boys were kept home for spring farm chores. All teachers

brought to bear their standard techniques to attempt to sustain the progress of pupils returning from absences.

Reinforcement activities were included in most of the instructional episodes, but in neither the pilot run nor the experimental run was there provision for an all-inclusive review for the post-instructional measurement. Comprehensive review may have sound pedagogical value, but the investigator did not want to risk creation of anxiety among pupils and instructors by special preparation for the test.

Every class took the post-instructional test at the same time and within 48 hours of completion of the final episode. Several children, from different classes, gratuitously commented that the test was "fun."

The test in both forms was read to each class by the regular teacher, except in the make-up sessions where the investigator read the questions. The children were expected to read along in their own test booklets, and had to be able to interpret the two reference tables. Instructions were given to provide an answer for every question. Sufficient time was given to permit every child to complete each test item.

The scores from the test were employed as the measurements for evaluating the hypotheses. The data are reported in the 4th chapter.

CHAPTER IV

RESULTS OF THE STATISTICAL ANALYSIS

In the present study a major conceptual scheme of science, the planetary atomic model (PAM), was the basis for a curriculum experiment in middle elementary and pre-secondary classes. The instructional episodes were presented by the regular classroom teacher. The goals for each instructional episode and the instrument to measure pupil attainment of the objectives were derived from hierarchies of cognitive complexity suggested from the literature. The objective of an episode and its measurements has one of four designations:

1. Factual-conceptual, background to the PAM;
2. Factual-conceptual, PAM;
3. Inferential, background to the PAM;
4. Inferential, PAM.

The measurement instrument was a multiple choice test composed of 48 items with 4 options per item. Jury procedures were employed for validation of content of test questions and to check correspondence of instructional

and measurement objectives.

As the general outcome, a sequence of instructional episodes was developed and tested for feasibility with middle elementary and pre-secondary classes which included experiences in a cognitive hierarchy leading to and pertaining to the planetary atomic model (PAM).

The bulk of the statistical computations required for evaluation of the hypotheses were performed by the computer centers of Harpur (Binghamton) and Cortland Colleges of State University of New York. Calculations for the pilot run and the estimates of test instrument reliability for the pilot and the experiment were processed by the investigator.

Computer programs developed by the Health Services Computing Facility, UCLA, were utilized in testing the hypotheses, as follows: hypotheses 1a through 8b, analysis of variance, BMD01V (1966) and hypotheses 9a through 16b, in part, product-moment correlation, BMD03D (1966).

Data are presented in tabular form in numerical order of the hypotheses.

For hypotheses nos. 1a through 4b analysis of variance

was used to assess the significance of the number of correct answers by grade level of pre and post instructional testing for experimental versus reference ("control") classes for each instructional objective.

The remaining hypotheses, nos. 5a through 16b, apply to post-instructional scores of experimental classes only.

For hypotheses nos. 5a through 8b analysis of variance was used to assess the significance of the number of correct answers on the post-instructional test by sex and grade level for each instructional objective.

For hypotheses nos. 9a through 16b product-moment correlation and the "t" test for zero rho were used to assess the significance of the correlation from a population correlation of zero of IQ by sex and grade level versus the number of correct answers on the post-instructional test for each instructional objective.

To facilitate reporting the statistical analysis, the chapter, beginning with Table IV, has been organized as follows:

1. Each hypothesis is stated in the title of at least one table;
2. A discussion of the data is presented on the page with a table, or on the page between two related tables, or on the page following a table;
3. Data for summarizing the estimate of test reliability are presented in Table XLIV;
4. Data and discussion of the possible significance of accruals attained by reference classes are presented following Table XIX;
5. A discussion of the probability of a statistically significant comparison by chance is presented at the end of the chapter.

TABLE IV

Analysis of Variance Applied to Hypothesis No. 1a*: Middle Elementary Pupils Make No Significant Attainment on the Factual-Conceptual Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Are Background for Presentation of the Planetary Atomic Model.

*Pre-Instructional Measurement

Instructional Objective	Middle Elementary Group Identity	N	Mean†	Standard Deviation
Factual-Conceptual, Background	Experimental	57	1.8246	.8889
	Reference	56	1.4464	.9894
		113		

†n = 4

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	F-Ratio
Treatment (between)	4.0390	1	4.0390	4.5708
Error (within)	98.0844	111	0.8836	
Total	102.1234	112		

From Table IV the pre-instructional factual-conceptual background means of the middle elementary experimental and references classes are, respectively, 1.8246 and 1.4464. At α = .01 the tabled value of F with 1 and 111 degrees of freedom is 6.89, therefore, the computed F-ratio of 4.5708 is not significant. The difference in attainment of these classes measured on the pre-instructional factual-conceptual background objective may be attributed to chance.

From Table V the post-instructional experimental middle elementary mean is 3.2632 and the reference group mean is 1.5337. At α = .01 the tabled value of F with 1 and 111 degrees of freedom is 6.89. Therefore, the computed F-ratio of 148.5613 is very highly significant and hypothesis 1a is rejected.

TABLE V

Analysis of Variance Applied to Hypothesis No. 1a: Middle Elementary Pupils Make No Significant Attainment on the Factual-Conceptual Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Are Background for Presentation of the Planetary Atomic Model.

*Post-Instructional Measurement

Instructional Objectives	Middle Elementary Group Identity	N	Mean*	Standard Deviation
Factual-Conceptual, Background	Experimental	57	3.2632	0.7447
	Reference	56	1.5357	0.7619
		113		

*n = 4

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	F-Ratio
Treatment (between)	84.2930	1	84.2930	148.5613
Error (within)	62.9809	111	0.5674	
Total	147.2738	112		

TABLE VI

Analysis of Variance Applied to Hypothesis No. 1b*: Middle Elementary Pupils Make No Significant Attainment on the Factual-Conceptual Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Pertain to the Planetary Atomic Model.

*Pre-Instructional Measurement

Instructional Objectives	Middle Elementary Group Identity	N	Mean*	Standard Deviation
Factual-Conceptual, PAM	Experimental	57	3.2632	1.4458
	Reference	56	2.9821	1.4831
		113		

*n = 12

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	F-Ratio
Treatment (between)	2.2307	1	2.2307	1.0402
Error (within)	238.0340	111	2.1445	
Total	240.2647	112		

From Table VI the pre-instructional factual-conceptual PAM means of the middle elementary experimental and reference classes are, respectively, 3.2632 and 2.9821. At α = .01 the tabled value of F with 1 and 111 degrees of freedom is 6.89, therefore, the computed F-ratio of 1.0402 is not significant. The difference in attainment of these classes measured on the pre-instructional factual-conceptual PAM objective may be attributed to chance.

From Table VII the post-instructional experimental middle elementary mean is 8.0175 and the reference group mean is 2.9286. At α = .01 the tabled value of F with 1 and 111 degrees of freedom is 6.89. Therefore, the computed F-ratio of 187.6663 is very highly significant and hypothesis 1b is rejected.

TABLE VII

Analysis of Variance Applied to Hypothesis No. 1b*: Middle Elementary Pupils Make No Significant Attainment on the Factual-Conceptual Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Pertain to the Planetary Atomic Model.

*Post-Instructional Measurement

Instructional Objective	Middle Elementary Group Identity	N	Mean∓	Standard Deviation
Factual-Conceptual, PAM	Experimental	57	8.0175	2.3337
	Reference	56	2.9286	1.5238
		113		

∓n = 12

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	F-Ratio
Treatment (between)	731.5513	1	731.5513	187.6663
Error (within)	432.6946	111	3.8981	
Total	1164.2458	112		

TABLE VIII

Analysis of Variance Applied to Hypothesis No. 2a*: Middle Elementary Pupils Make No Significant Attainment on the Inferential Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Are Background For Presentation of the Planetary Atomic Model.

*Pre-Instructional Measurement

Instructional Objective	Middle Elementary Group Identity	N	Mean*	Standard Deviation
Inferential, Background	Experimental	57	6.5263	2.1803
	Reference	56	5.9821	2.1867
		113		

*n = 16

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	F-Ratio
Treatment (between)	8.3648	1	8.3648	1.7546
Error (within)	529.1909	111	4.7675	
Total	537.5557	112		

From Table VIII the pre-instructional inferential background means of middle elementary experimental and reference classes are, respectively, 6.5263 and 5.9821. At α = .01 the tabled value of F with 1 and 111 degrees of freedom is 6.89, therefore, the computed F-ratio of 1.7546 is not significant. The difference in attainment of these classes measured on the pre-instructional inferential background objective may be attributed to chance.

From Table IX, the post-instructional experimental middle elementary mean is 10.7018 and the reference group mean is 6.2679. At α = .01 the tabled value of F with 1 and 111 degrees of freedom is 6.89. Therefore, the computed F-ratio of 124.0511 is very highly significant and hypothesis 2a is rejected.

TABLE IX

Analysis of Variance Applied to Hypothesis No. 2a*: Middle Elementary Pupils Make No Significant Attainment on the Inferential Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Are Background For Presentation of the Planetary Atomic Model.

*Post-Instructional Measurement

Instructional Objective	Middle Elementary Group Identity	N	Mean*	Standard Deviation
Inferential, Background	Experimental	57	10.7018	2.2517
	Reference	56	6.2679	1.9678
		113		

*n = 16

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	F-Ratio
Treatment (between)	555.3357	1	555.3357	124.0511
Error (within)	496.9104	111	4.4767	
Total	1052.2461	112		

TABLE X

Analysis of Variance Applied to Hypothesis No. 2b*: Middle Elementary Pupils Make No Significant Attainment on the Inferential Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Pertain to the Planetary Atomic Model.

*Pre-Instructional Measurement

Instructional Objective	Middle Elementary Group Identity	N	Mean*	Standard Deviation
Inferential, PAM	Experimental	57	3.8246	2.2130
	Reference	56	3.7321	1.7938
		113		

‡n = 16

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	F-Ratio
Treatment (between)	.2413	1	0.2413	0.0594
Error (within)	451.2266	111	4.0651	
Total	451.4678	112		

From Table X the pre-instructional inferential PAM means of the middle elementary experimental and reference classes are, respectively, 3.8246 and 3.7321. At α = .01 the tabled value of F with 1 and 111 degrees of freedom is 6.89, therefore, the computed F-ratio of 0.0594 is not significant. The difference in attainment of these classes measured on the pre-instructional inferential PAM objective may be attributed to chance.

From Table XI the post-instructional experimental middle elementary mean is 11.5088 and the reference group mean is 4.2679. At α = .01 the tabled value of F with 1 and 111 degrees of freedom is 6.89. Therefore, the computed F-ratio of 310.6370 is very highly significant and hypothesis 2b is rejected.

TABLE XI

Analysis of Variance Applied to Hypothesis No.2b*: Middle Elementary Pupils Make No Significant Attainment on the Inferential Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Pertain to the Planetary Atomic Model.

*Post-Instruction Measurement

Instructional Objective	Middle Elementary Group Identity	N	Mean▼	Standard Deviation
Inferential, PAM	Experimental	57	11.5088	2.3537
	Reference	56	4.2679	1.9954
		113		

▼n = 16

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	F-Ratio
Treatment (between)	1481.0557	1	1481.0557	310.6370
Error (within)	529.2261	111	4.7678	
Total	2010.2817	112		

TABLE XII

Analysis of Variance Applied to Hypothesis No. 3a*: Pre-Secondary Pupils Make No Significant Attainment on the Factual-Conceptual Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Are Background for Presentation of the Planetary Atomic Model.

*Pre-Instructional Measurement

Instructional Objective	Pre-Secondary Group Identity	N	Mean*	Standard Deviation
Factual-Conceptual, Background	Experimental	59	1.6441	0.9241
	Reference	54	1.8704	0.9526
		113		

*n = 4

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	F-Ratio
Treatment (between)	1.4439	1	1.4439	1.6419
Error (within)	97.6176	111	0.8794	
Total	99.0615	112		

From Table XII the pre-instructional factual-conceptual background means of the pre-secondary experimental and reference classes are, respectively, 1.6441 and 1.8704. At α = .01 the tabled value of F with 1 and 111 degrees of freedom is 6.89, therefore, the computed F-ratio of 1.6419 is not significant. The difference in attainment of these classes measured on the pre-instructional factual-conceptual PAX objective may be attributed to chance.

From Table XIII the post-instructional experimental pre-secondary mean is 2.5763 and the reference group mean is 1.8333. At α = .01 the tabled value of F with 1 and 111 degrees of freedom is 6.89. Therefore, the computed F-ratio of 14.1700 is significant beyond the .01 level and hypothesis 3a is rejected.

TABLE XIII

Analysis of Variance Applied to Hypothesis No. 3a*: Pre-Secondary Pupils Make No Significant Attainment on the Factual-Conceptual Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Are Background For Presentation of the Planetary Atomic Model.

*Post-Instructional Measurement

Instructional Objective	Pre-Secondary Group Identity	N	Mean*	Standard Deviation
Factual-Conceptual, Background	Experimental	59	2.5763	1.1018
	Reference	54	1.8333	0.9857
		113		

*n = 4

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	F-Ratio
Treatment (between)	15.5622	1	15.5622	14.1700
Error (within)	121.9061	111	1.0983	
Total	137.4683	112		

TABLE XIV

Analysis of Variance Applied to Hypothesis No. 3b*: Pre-Secondary Pupils Make No Significant Attainment on the Factual-Conceptual Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Pertain to the Planetary Atomic Model.

*Pre-Instructional Measurement

Instructional Objective	Pre-Secondary Group Identity	N	Mean‡	Standard Deviation
Factual-Conceptual, PAM	Experimental	59	3.4746	1.3177
	Reference	54	3.5556	1.6214
		113		

‡n = 12

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	F-Ratio
Treatment (between)	0.1849	1	0.1849	0.0855
Error (within)	240.0445	111	2.1626	
Total	240.2293	112		

From Table XIV the pre-instructional factual-conceptual PAM means of the pre-secondary experimental and reference classes are, respectively, 3.4746 and 3.5556. At $\alpha = .01$ the tabled value of F with 1 and 111 degrees of freedom is 6.89, therefore, the computed F-ratio of 0.0855 is not significant. The difference in attainment of these classes measured on the pre-instructional factual-conceptual PAM objective may be attributed to chance.

From Table XV the post-instructional experimental pre-secondary mean is 6.1017 and the reference group mean is 3.4815. At $\alpha = .01$ the tabled value of F with 1 and 111 degrees of freedom is 6.89. Therefore, the computed F-ratio of 50.3348 is highly significant and hypothesis 3b is rejected.

It is noted that the findings from evaluation of hypothesis 3b have positive correspondence with research reported by Reid (1952).

TABLE XV

Analysis of Variance Applied to Hypothesis No. 3b*: Pre-Secondary Pupils Make No Significant Attainment on the Factual-Conceptual Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Pertain to the Planetary Atomic Model.

*Post-Instructional Measurement

Instructional Objective	Pre-Secondary Group Identity	N	Mean*	Standard Deviation
Factual-Conceptual, PAM	Experimental	59	6.1017	2.3096
	Reference	54	3.4815	1.4888
		113		

*n = 12

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	F-Ratio
Treatment (between)	193.5711	1	193.5711	50.3348
Error (within)	426.8694	111	3.8457	
Total	620.4404	112		

TABLE XVI

Analysis of Variance Applied to Hypothesis No. 4a*: Pre-Secondary Pupils Make No Significant Attainment on the Inferential Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Are Background for Presentation of the Planetary Atomic Model.

*Pre-Instructional Measurement

Instruction Objective	Pre-Secondary Group Identity	N	Mean*	Standard Deviation
Inferential, Background	Experimental	59	6.8136	1.8889
	Reference	54	6.8704	2.6210
		113		

*n = 16

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	F-Ratio
Treatment (between)	0.0910	1	0.0910	0.0177
Error (within)	571.0391	111	5.1445	
Total	571.1299	112		

From Table XVI the pre-instructional inferential background means of the pre-secondary experimental and reference classes are, respectively, 6.8136 and 6.8704. At α = .01 the tabled value of F with 1 and 111 degrees of freedom is 6.89, therefore, the computed F-ratio of 0.0177 is not significant. The difference in attainment of these classes measured on the pre-instructional inferential background objective may be attributed to chance.

From Table XVII the post-instructional experimental pre-secondary mean is 10.5932 and the reference group mean is 7.7407. At α = .01 the tabled value of F with 1 and 111 degrees of freedom is 6.89. Therefore, the computed F-ratio of 44.0102 is highly significant and hypothesis no. 4a is rejected.

An assessment and discussion of the significance of the difference between pre and post instructional means of the reference category described in hypothesis no. 4a, and other hypotheses, are presented following Table XIX.

TABLE XVII

Analysis of Variance Applied to Hypothesis No. 4a*: Pre-Secondary Pupils Make No Significant Attainment on the Inferential Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Are Background for Presentation of the Planetary Atomic Model.

*Post-Instructional Measurement

Instructional Objective	Pre-Secondary Group Identity	N	Mean†	Standard Deviation
Inferential, Background	Experimental	59	10.5932	2.3053
	Reference	54	7.7407	2.2586
		113		

†n = 16

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	F-Ratio
Treatment (between)	229.4101	1	229.4101	44.0102
Error (within)	578.6050	111	5.2127	
Total	808.0149	112		

TABLE XVIII

Analysis of Variance Applied to Hypothesis No. 4b*: Pre-Secondary Pupils Make No Significant Attainment on the Inferential Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Pertain to the Planetary Atomic Model.

*Pre-Instructional Measurement

Instructional Objective	Pre-Secondary Group Identity	N	Mean*	Standard Deviation
Inferential, PAM	Experimental	59	6.0678	2.1961
	Reference	54	5.6111	1.8876
		113		

*n = 16

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	F-Ratio
Treatment (between)	5.8803	1	5.8803	1.3930
Error (within)	468.5605	111	4.2213	
Total	474.4407	112		

From Table XVIII the pre-instructional inferential PAX mean of the pre-secondary experimental and reference classes are, respectively, 6.0678 and 5.6111. At $\alpha = .01$ the tabled value of F with 1 and 111 degrees of freedom is 6.89, therefore, the computed F-ratio of 1.3930 is not significant. The difference in attainment of these classes measured on the pre-instructional inferential PAX objective may be attributed to chance.

From Table XIX the post-instructional experimental pre-secondary mean is 9.8475 and the reference group mean is 6.0741. At $\alpha = .01$ the tabled value of F with 1 and 111 degrees of freedom is 6.89. Therefore, the computed F-ratio of 89.6002 is highly significant and hypothesis no. 4b is rejected.

TABLE XIX

Analysis of Variance Applied to Hypothesis No. 4b*: Pre-Secondary Pupils Make No Significant Attainment on the Inferential Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Pertain to the Planetary Atomic Model.

*Post-Instructional Measurement

Instructional Objective	Pre-Secondary Group Identity	N	Mean†	Standard Deviation
Inferential, PAM	Experimental	59	9.8475	2.3179
	Reference	54	6.0741	1.8719
		113		

†n = 16

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	F-Ratio
Treatment (between)	401.4480	1	401.4480	89.6002
Error (within)	497.3286	111	4.4804	
Total	898.7766	112		

The possibility has been explored that the attainments reported for the experimental classes could, at least in part, be attributed to informal accruals or maturation during the period of the treatment. To make an estimate of such a possibility, the difference between a reference ("control") group's pre-instructional mean and post-instructional mean for a given objective was evaluated for significance using the t test for correlated observations. The disposition for assessment of the computed t-ratio was the one-tail test at $\alpha = .01$.

The greatest difference between pre and post instructional means for a reference group was registered in the pre-secondary classroom category on the inferential background objective, hypothesis no. 4a. As reported in Tables XVI and XVII respectively, the mean of the pre-instructional scores was 6.8704 and the mean of the post-instructional scores was 7.7407; the difference equals .8703. For N=54 the standard error of difference between

the means was calculated to be approximately 1.1310. The t-ratio was approximately .769 and since it was less than one, the measured gain was not significant. For both grade categories, middle elementary and pre-secondary, on the other instructional objectives, indices of attainments registered by reference groups during the experiment were also non-significant, or they were regressive; therefore, no supplementary tabular summary is presented beyond that recorded in Tables IV through XIX.

If pupils of the reference classes are considered to have been essentially random representatives of the available classes, then it is submitted that there is no apparent evidence to indicate that the magnitude of the attainments made by the experimental groups could be imputed to maturation or casual accruals during the seven week tenure of the investigation.

TABLE XX

Analysis of Variance Applied to Hypothesis No. 5a: There Is No Significant Difference Attributable to Sex in Attainment of Middle Elementary Pupils on the Factual-Conceptual Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Are Background for Presentation of the Planetary Atomic Model.

Post-Instructional Measurement

Instructional Objective	Middle Elementary Experimental Group Identity	N	Mean'	Standard Deviation
Factual-Conceptual, Background	Boys	30	3.3333	0.6609
	Girls	27	3.1852	0.8338
		57		

n = 4

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	F-Ratio
Treatment (between)	0.3139	1	0.3119	0.5580
Error (within)	30.7407	55	0.5589	
Total	31.0546	56		

Table XX refers to the difference in post-instructional means by sex for middle elementary experimental classes on the factual-conceptual background objective. The boys' mean is 3.3333 and the girls' mean is 3.1852. At α = .01 the tabled value of F with 1 and 55 degrees of freedom is 7.12. The computed F-ratio of 0.5580 is not significant indicating a chance difference in means. Hypothesis no. 5a cannot be rejected.

Table XXI refers to the difference in post-instructional means by sex for middle elementary experimental classes on the factual-conceptual PAK objective. The boys' mean is 7.9333 and girls' mean is 8.1111. At α = .01 the tabled value of F with 1 and 55 degrees of freedom is 7.12. The computed F-ratio of 0.0811 is not significant indicating a chance difference in means. Hypothesis no. 5b cannot be rejected.

TABLE XXI

Analysis of Variance Applied to Hypothesis No. 5b: There Is No Significant Difference Attributable to Sex in Attainment of Middle Elementary Pupils on the Factual-Conceptual Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Pertain to the Planetary Atomic Model.

Post-Instructional Measurement

Instructional Objective	Middle Elementary Experimental Group Identity	N	Mean*	Standard Deviation
Factual-Conceptual, PAM	Boys	30	7.9333	2.2273
	Girls	27	8.1111	2.4859
		57		

*n = 12

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	F-Ratio
Treatment (between)	0.4491	1	0.4491	0.0811
Error (within)	304.5330	55	5.5370	
Total	304.9819	56		

TABLE XXII

Analysis of Variance Applied to Hypothesis No. 6a: There Is No Significant Difference Attributable to Sex in Attainment of Middle Elementary Pupils on the Inferential Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Are Background for Presentation of the Planetary Atomic Model.

Post-Instructional Measurement

Instructional Objective	Middle Elementary Experimental Group Identity	N	Mean*	Standard Deviation
Inferential, Background	Boys	30	11.1333	2.1930
	Girls	27	10.2222	2.2589
		57		

*n = 16

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	F-Ratio
Treatment (between)	11.7965	1	11.7965	2.3842
Error (within)	272.1331	55	4.9479	
Total	283.9294	56		

Table XXII refers to the difference in post-instructional means by sex for middle elementary experimental classes on the inferential background objective. The boys' mean is 11.1333 and the girls' mean is 10.2222. At α = .01 the tabled value of F with 1 and 55 degrees of freedom is 7.12. The computed F-ratio of 2.3842 is not significant indicating a chance difference in means. Hypothesis no. 6a cannot be rejected.

Table XXIII refers to the difference in post-instructional means by sex for middle elementary experimental classes on the inferential PAM objective. The boys' mean is 11.4333 and the girls' mean is 11.5926. At α = .01 the tabled value of F with 1 and 55 degrees of freedom is 7.12. The computed F-ratio of 0.0640 is not significant indicating a chance difference in means. Hypothesis no. 6b cannot be rejected.

TABLE XXIII

Analysis of Variance Applied to Hypothesis No. 6b: There Is No Significant Difference Attributable to Sex in Attainment of Middle Elementary Pupils On the Inferential Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Pertain to the Planetary Atomic Model.

Post-Instructional Measurement

Instructional Objective	Middle Elementary Experimental Group Identity	N	Mean*	Standard Deviation
Inferential, PAM	Boys	30	11.4333	2.4731
	Girls	27	11.5926	2.2576
		57		

*n = 16

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	F-Ratio
Treatment (between)	0.3604	1	0.3604	0.0640
Error (within)	309.8845	55	5.6343	
Total	310.2449	56		

TABLE XXIV

Analysis of Variance Applied to Hypothesis No. 7a: There Is No Significant Difference Attributable to Sex in Attainment of Pre-Secondary Pupils on the Factual-Conceptual Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Are Background for Presentation of the Planetary Atomic Model.

Post-Instructional Measurement

Instructional Objective	Pre-Secondary Experimental Group Identity	N	Mean‡	Standard Deviation
Factual-Conceptual, Background	Boys	29	3.0000	0.8864
	Girls	30	2.1667	1.1472
		59		

‡n = 4

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	F-Ratio
Treatment (between)	10.2401	1	10.2401	9.7012
Error (within)	60.1665	57	1.0556	
Total	70.4067	58		

Table XXIV refers to the difference in post-instructional means by sex for pre-secondary experimental classes on the factual-conceptual background objective. The boys' mean is 3.0000 and the girls' mean is 2.1667. At α = .01 the tabled value of F with 1 and 57 degrees of freedom is 7.11. The computed F-ratio of 9.7012 is significant beyond the .01 level. Hypothesis no. 7a is rejected; this particular outcome is discussed in chapter no. 5.

Table XXV refers to the difference in post-instructional means by sex for pre-secondary experimental classes on the factual-conceptual PAM objective. The boys' mean is 6.6552 and the girls' mean is 5.5667. At α = .01 the tabled value of F with 1 and 57 degrees of freedom is 7.11. The computed F-ratio of 3.4115 is not significant. Hypothesis no. 7b cannot be rejected.

TABLE XXV

Analysis of Variance Applied to Hypothesis No. 7b: There Is No Significant Difference Attributable to Sex in Attainment of Pre-Secondary Pupils on the Factual-Conceptual Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Pertain to the Planetary Atomic Model.

Post-Instructional Measurement

Instructional Objective	Pre-Secondary Experimental Group Identity	N	Mean*	Standard Deviation
Factual-Conceptual, PAM	Boys	29	6.6552	2.3494
	Girls	30	5.5667	2.1764
		59		

*n = 12

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	F-Ratio
Treatment (between)	17.4714	1	17.4714	3.4115
Error (within)	291.9180	57	5.1214	
Total	309.3892	58		

TABLE XXVI

Analysis of Variance Applied to Hypothesis No. 8a: There Is No Significant Difference Attributable to Sex in Attainment of Pre-Secondary Pupils on the Inferential Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Are Background for Presentation of the Planetary Atomic Model.

Post-Instructional Measurement

Instructional Objective	Pre-Secondary Experimental Group Identity	N	Mean*	Standard Deviation
Inferential, Background	Boys	29	11.2414	2.3246
	Girls	30	9.9667	2.1413
		59		

*n = 16

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	F-Ratio
Treatment (between)	23.9603	1	23.9603	4.8042
Error (within)	284.2766	57	4.9873	
Total	308.2368	58		

Table XXVI refers to the difference in post-instructional means by sex for pre-secondary experimental classes on the inferential background objective. The boys' mean is 11.2414 and the girls' mean is 9.9667. At α = .01 the tabled value of F with 1 and 57 degrees of freedom is 7.11. The computed F-ratio of 4.8042 is not significant. Hypothesis no. 8a cannot be rejected.

Table XXVII refers to the difference in post-instructional means by sex for pre-secondary experimental classes on the inferential PAM objective. The boys' mean is 10.3103 and the girls' mean is 9.4000. At α = .01 the tabled value of F with 1 and 57 degrees of freedom is 7.11. The computed F-ratio of 2.3264 is not significant. Hypothesis no. 8b cannot be rejected.

TABLE XXVII

Analysis of Variance Applied to Hypothesis No. 8b: There Is No Significant Difference Attributable to Sex in Attainment of Pre-Secondary Pupils on the Inferential Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Pertain to the Planetary Atomic Model.

Post-Instructional Measurement

Instructional Objective	Pre-Secondary Experimental Group Identity	N	Mean*	Standard Deviation
Inferential, PAM	Boys	29	10.3103	2.4069
	Girls	30	9.4000	2.1751
		59		

*n = 16

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	F-Ratio
Treatment (between)	12.2202	1	12.2202	2.3264
Error (within)	299.4065	57	5.7527	
Total	311.6265	58		

TABLE XXVIII

Product-Moment Correlation and "t" Test of Significance for a Population Correlation Coefficient of Zero Applied to Hypothesis No. 9a: There Is No Significant Correlation Between a Measure of Mental Ability of Middle Elementary Boys and Their Attainment on the Factual-Conceptual Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Are Background for Presentation of the Planetary Atomic Model.

Post-Instructional Measurement

Variable	N and Group Identity	Mean	Standard Deviation	Sample r	d.f.	Min. r for Signif. at .01
Factual-Conceptual, Background	30 M.E.$_X$ Boys	3.333*	0.6609	.3534	28	.463
IQ (T-Scaled)		49.4333	9.8426			

*n = 4

Table XXVIII refers to the "t" test for zero rho relevant to the correlation between middle elementary experimental boys' IQ and their post-instructional attainment on the factual-conceptual background objective. For 28 degrees of freedom the minimum correlation coefficient needed for significance at $\alpha = .01$ is $\pm .463$, therefore the sample coefficient of .3534 is not significant. Hypothesis 9a cannot be rejected.

TABLE XXIX

Product-Moment Correlation and "t" Test of Significance for a Population Correlation Coefficient of Zero Applied to Hypothesis No. 9b: There Is No Significant Correlation Between a Measure of Mental Ability of Middle Elementary Boys and Their Attainment on the Factual-Conceptual Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Pertain to the Planetary Atomic Model.

Post-Instruction Measurement

Variable	N and Group Identity	Mean	Standard Deviation	Sample r	d.f.	Min. r for Signif. at .01
Factual-Conceptual, PAM	30 M.E. Boys^X	7.9333*	2.2273	.3726	28	.463
IQ (T-Scaled)		49.4333	9.8426			

*n = 12

Table XXIX refers to the "t" test for zero rho relevant to the correlation between middle elementary experimental boys' IQ and their post-instructional attainment on the factual-conceptual PAM objective. For 28 degrees of freedom the minimum correlation coefficient needed for significance at $\alpha = .01$ is $\pm .463$, therefore the sample coefficient of .3726 is not significant. Hypothesis 9b cannot be rejected.

TABLE XXX

Product-Moment Correlation and "t" Test of Significance for a Population Correlation Coefficient of Zero Applied to Hypothesis No. 10a: There Is No Significant Correlation Between a Measure of Mental Ability of Middle Elementary Girls and Their Attainment on the Factual-Conceptual Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Are Background for Presentation of the Planetary Atomic Model.

Post-Instructional Measurement

Variable	N and Group Identity	Mean	Standard Deviation	Sample r	d.f.	Min. r for Signif. at .01
Factual-Conceptual, Background	27 ME_y Girls	3.1852*	0.8338			
				.0767	25	.487
IQ (T-Scaled)		49.5185	9.8738			

*n = 4

Table XXX refers to the "t" test for zero rho relevant to the correlation between middle elementary experimental girls' IQ and their post-instructional attainment on the factual-conceptual background objective. For 25 degrees of freedom the minimum correlation coefficient needed for significance at $\alpha = .01$ is $\pm .487$, therefore the sample coefficient of .0767 is not significant. Hypothesis 10a cannot be rejected.

TABLE XXXI

Product-Moment Correlation and "t" Test of Significance for a Population Correlation Coefficient of Zero Applied to Hypothesis No. 10b: There Is No Significant Correlation Between a Measure of Mental Ability of Middle Elementary Girls and Their Attainment on the Factual-Conceptual Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Pertain to the Planetary Atomic Model.

Post-Instructional Measurement

Variable	N and Group Identity	Mean	Standard Deviation	Sample r	d.f.	Min. r for Signif. at .01
Factual-Conceptual, PAM	27 M.E. Girls^{X}	8.1111*	2.4859	.0132	25	.487
IQ (T-Scaled)		49.5185	9.8738			

*n = 12

Table XXXI refers to the "t" test for zero rho relevant to the correlation between middle elementary experimental girls' IQ and their post-instructional attainment on the factual-conceptual background objective. For 25 degrees of freedom the minimum correlation coefficient needed for significance at $\alpha = .01$ is $\pm .487$, therefore the sample coefficient of .0132 is not significant. Hypothesis 10b cannot be rejected.

TABLE XXXII

Product-Moment Correlation and "t" Test of Significance for a Population Correlation Coefficient of Zero Applied to Hypothesis No. 11a: There Is No Significant Correlation Between a Measure of Mental Ability of Middle Elementary Boys and Their Attainment on the Inferential Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which are Background for Presentation of the Planetary Atomic Model.

Post-Instructional Measurement

Variable	N and Group Identity	Mean	Standard Deviation	Sample r	d.f.	Min. r for Signif. at .01
Inferential, Background	30 M.E. Boys$_X$	11.1333*	2.1930	.4030	28	.463
IQ (T-Scaled)		49.4333	9.8426			

*n = 16

Table XXXII refers to the "t" test for zero rho relevant to the correlation between middle elementary experimental boys' IQ and their post-instructional attainment on the inferential background objective. For 28 degrees of freedom the minimum correlation coefficient needed for significance at $\alpha = .01$ is $\pm .463$, therefore the sample coefficient of .4030 is not significant. Hypothesis 11a cannot be rejected.

TABLE XXXIII

Product-Moment Correlation and "t" Test of Significance for a Population Correlation Coefficient of Zero Applied to Hypothesis No. 11b: There Is No Significant Correlation Between a Measure of Mental Ability of Middle Elementary Boys and Their Attainment on the Inferential Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Pertain to the Planetary Atomic Model.

Post-Instructional Measurement

Variable	N and Group Identity	Mean	Standard Deviation	Sample r	d.f.	Min. r for Signif. at .01
Inferential, PAM	30 M.E. Boys[X]	11.4333*	2.4731	.3207	28	.463
IQ (T-Scaled)		49.4333	9.8426			

*n = 16

Table XXXIII refers to the "t" test for zero rho relevant to the correlation between middle elementary boys' IQ and their post-instructional attainment on the inferential PAM objective. For 28 degrees of freedom the minimum correlation coefficient needed for significance at $\alpha = .01$ is $\pm .463$, therefore the sample coefficient of .3207 is not significant. Hypothesis 11b cannot be rejected.

TABLE XXXIV

Product-Moment Correlation and "t" Test of Significance for a Population Correlation Coefficient of Zero Applied to Hypothesis No. 12a: There Is No Significant Correlation Between a Measure of Mental Ability of Middle Elementary Girls and Their Attainment on the Inferential Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Are Background for Presentation of the Planetary Atomic Model.

Post-Instructional Measurement

Variable	N and Group Identity	Mean	Standard Deviation	Sample r	d.f.	Min. r for Signif. at .01
Inferential, Background	27 M.E. Girls[X]	10.2222*	2.2589			
				.1205	25	.487
IQ (T-Scaled)		49.5185	9.8738			

*n = 16

Table XXXIV refers to the "t" test for zero rho relevant to the correlation between middle elementary girls' IQ and their post-instructional attainment on the inferential background objective. For 25 degrees of freedom the minimum correlation coefficient needed for significance at $\alpha = .01$ is $\pm .487$, therefore the sample coefficient of .1205 is not significant. Hypothesis 12a cannot be rejected.

TABLE XXXV

Product-Moment Correlation and "t" Test of Significance for a Population Correlation Coefficient of Zero Applied to Hypothesis No. 12b: There Is No Significant Correlation Between a Measure of Mental Ability of Middle Elementary Girls and Their Attainment on the Inferential Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Pertain to the Planetary Atomic Model.

Post-Instructional Measurement

Variable	N and Group Identity	Mean	Standard Deviation	Sample r	d.f.	Min. r for Signif. at .01
Inferential, PAM	27 M.E. Girls^X	11.5926*	2.2576	.3756	25	.487
IQ (T-Scaled)		49.5185	9.8738			

*n = 16

Table XXXV refers to the "t" test for zero rho relevant to the correlation between middle elementary girls' IQ and their post-instructional attainment on the inferential PAM objective. For 25 degrees of freedom the minimum correlation needed for significance at $\alpha = .01$ is $\pm .487$, therefore the sample coefficient of .3756 is not significant. Hypothesis 12b cannot be rejected.

TABLE XXXVI

Product-Moment Correlation and "t" Test of Significance for a Population Correlation Coefficient of Zero Applied to Hypothesis No. 13a: There Is No Significant Correlation Between a Measure of Mental Ability of Pre-Secondary Boys and Their Attainment on the Factual-Conceptual Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Are Background for Presentation of the Planetary Atomic Model.

Post-Instructional Measurement

Variable	N and Group Identity	Mean	Standard Deviation	Sample r	d.f.	Min. r for Signif. at .01
Factual-Conceptual, Background	29 P.S. Boys[X]	3.000*	.8864	.1663	27	.470
IQ (T-Scaled)		49.5862	9.9338			

*n = 4

Table XXXVI refers to the "t" test for zero rho relevant to the correlation between pre-secondary boys' IQ and their post-instructional attainment on the factual-conceptual background objective. For 27 degrees of freedom the minimum correlation needed for significance at $\alpha = .01$ is $\pm .470$, therefore the sample coefficient of .1663 is not significant. Hypothesis 13a cannot be rejected.

TABLE XXXVII

Product-Moment Correlation and "t" Test of Significance for a Population Correlation Coefficient of Zero Applied to Hypothesis No. 13b: There Is No Significant Correlation Between a Measure of Mental Ability of Pre-Secondary Boys and Their Attainment on the Factual-Conceptual Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Pertain to the Planetary Atomic Model.

Post-Instructional Measurement

Variable	N and Group Identity	Mean	Standard Deviation	Sample r	d.f.	Min. r for Signif. at .01
Factual-Conceptual, PAM	29 P.S. Boys*	6.6552*	2.3494	.2232	27	.470
IQ (T-Scaled)		49.5862	9.9338			

*n = 12

Table XXXVII refers to the "t" test for zero rho relevant to the correlation between pre-secondary boys' IQ and their post-instructional attainment on the factual-conceptual PAM objective. For 27 degrees of freedom the minimum correlation needed for significance at $\alpha = .01$ is $\pm .470$, therefore the sample coefficient of .2232 is not significant. Hypothesis 13b cannot be rejected.

TABLE XXXVIII

Product-Moment Correlation and "t" Test of Significance for a Population Correlation Coefficient of Zero Applied to Hypothesis No. 14a: There Is No Significant Correlation Between a Measure of Mental Ability of Pre-Secondary Girls and Their Attainment on the Factual-Conceptual Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Are Background for Presentation of the Planetary Atomic Model.

Post-Instructional Measurement

Variable	N and Group Identity	Mean	Standard Deviation	Sample r	d.f.	Min. r for Signif. at .01
Factual-Conceptual, Background	30 P.S. Girls$_X$	2.1667*	1.1472	-.1669	28	-.463
IQ (T-Scaled)		49.5333	10.0232			

*n = 4

Table XXXVIII refers to the "t" test for zero rho relevant to the correlation between pre-secondary girls' IQ and their post-instructional attainment on the factual-conceptual background objective. For 28 degrees of freedom the minimum correlation needed for significance at $\alpha = .01$ is $\pm .463$, therefore the sample coefficient of -.1669 is not significant. Hypothesis 14a cannot be rejected.

TABLE XXXIX

Product-Moment Correlation and "t" Test of Significance for a Population Correlation Coefficient of Zero Applied to Hypothesis No. 14b: There Is No Significant Correlation Between a Measure of Mental Ability of Pre-Secondary Girls and Their Attainment on the Factual-Conceptual Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Pertain to the Planetary Atomic Model.

Post-Instructional Measurement

Variable	N and Group Identity	Mean	Standard Deviation	Sample r	d.f.	Min. r for Signif. at .01
Factual-Conceptual, PAM	30 P.S. Girls[X]	5.5667*	2.1764	.1738	28	.463
IQ (T-Scaled)		49.5333	10.0232			

*n = 12

Table XXXIX refers to the "t" test for zero rho relevant to the correlation between pre-secondary girls' IQ and their post-instructional attainment on the factual-conceptual PAM objective. For 28 degrees of freedom the minimum correlation needed for significance at $\alpha = .01$ is $\pm .463$, therefore the sample coefficient of .1738 is not significant. Hypothesis 14b cannot be rejected.

TABLE XL

Product-Moment Correlation and "t" Test of Significance for a Population Correlation Coefficient of Zero Applied to Hypothesis No. 15a: There Is No Significant Correlation Between a Measure of Mental Ability of Pre-Secondary Boys and Their Attainment on the Inferential Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Are Background for Presentation of the Planetary Atomic Model.

Post-Instructional Measurement

Variable	N and Group Identity	Mean	Standard Deviation	Sample r	d.f.	Min. r for Signif. at .01
Inferential, Background	29 P.S. Boys*	11.2414*	2.3246	-.1858	27	-.470
IQ (T-Scaled)		49.5862	9.9338			

*n = 16

Table XL refers to the "t" test for zero rho relevant to the correlation between pre-secondary boys' IQ and their post-instructional attainment on the inferential background objective. For 27 degrees of freedom the minimum correlation needed for significance at α = .01 is ± .470, therefore the sample coefficient of -.1858 is not significant. Hypothesis 15a cannot be rejected.

TABLE XLI

Product-Moment Correlation and "t" Test of Significance for a Population Correlation Coefficient of Zero Applied to Hypothesis No. 15b: There Is No Significant Correlation Between a Measure of Mental Ability of Pre-Secondary Boys and Their Attainment on the Inferential Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Pertain to the Planetary Atomic Model.

Post-Instructional Measurement

Variable	N and Group Identity	Mean	Standard Deviation	Sample r	d.f.	Min. r for Signif. at .01
Inferential, PAM	29 P.S. Boys	10.3103*	2.4069			
				.0354	27	.470
IQ (T-Scaled)		49.5862	9.9338			

*n = 16

Table XLI refers to the "t" test for zero rho relevant to the correlation between pre-secondary boys' IQ and their post-instructional attainment on the inferential PAM objective. For 27 degrees of freedom the minimum correlation needed for significance at $\alpha = .01$ is $\pm .470$, therefore the sample coefficient of .0354 is not significant. Hypothesis 15b cannot be rejected.

TABLE XLII

Product-Moment Correlation and "t" Test of Significance for a Population Correlation Coefficient of Zero Applied to Hypothesis No. 16a: There Is No Significant Correlation Between a Measure Of Mental Ability of Pre-Secondary Girls and Their Attainment on the Inferential Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Are Background for Presentation of the Planetary Atomic Model.

Post-Instructional Measurement

Variable	N and Group Identity	Mean	Standard Deviation	Sample r	d.f.	Min. r for Signif. at .01
Inferential, Background	30 P.S. Girls	9.9667*	2.1413	.1840	28	.463
IQ (T-Scaled)		49.5333	10.0232			

*n = 16

Table XLII refers to the "t" test for zero rho relevant to the correlation between pre-secondary girls' IQ and their post-instructional attainment on the inferential background objective. For 28 degrees of freedom the minimum correlation coefficient needed for significance at $\alpha = .01$ is $\pm .463$, therefore the sample coefficient of .1840 is not significant. Hypothesis 16a cannot be rejected.

TABLE XLIII

Product-Moment Correlation and "t" Test of Significance for a Population Correlation Coefficient of Zero Applied to Hypothesis No. 16b: There Is No Significant Correlation Between a Measure of Mental Ability of Pre-Secondary Girls and Their Attainment on the Inferential Goal of Instruction From a Sequence of Classroom Cognitive Experiences Which Pertain to the Planetary Atomic Model.

Post-Instructional Measurement

Variable	N and Group Identity	Mean	Standard Deviation	Sample r	d.f.	Min. r for Signif. at .01
Inferential, PAM	30 P.S. Girls	9.4000*	2.1751			
				.1923	28	.463
IQ (T-Scaled)		49.5333	10.0232			

*n = 16

Table XLIII refers to the "t" test for zero rho relevant to the correlation between pre-secondary girls' IQ and their post-instructional attainment on the inferential background objective. For 28 degrees of freedom the minimum correlation needed for significance at $\alpha = .01$ is $\pm .463$, therefore the sample coefficient of .1923 is not significant. Hypothesis 16b cannot be rejected.

TABLE XLIV

Reliability Estimate of the Post-Instructional Test for the Experimental Classes and the Pilot Class Using the Kuder-Richardson Formula for Internal Consistency.

Class	N	No. of Items	Variance of Scores	Sum of Correctly Answered Scores	Sum of Products of Correct and Incorrect Answers by Item	r_{xx}
Experimental	116	48	38.70188	3627	126489	.77106
Pilot	21	48	66.9976	484	4518	.8573

Table XLIV refers to the data for estimating the reliability of the measurement instruments by means of the Kuder-Richardson formula for the index of internal consistency. The data were obtained from the post-instructional scores of the 4 experimental classes.

Appendix F records the number of correct answers for each test item of the experimental run; analagous information about the pilot run is presented in Appendix B, Table No. 2.

The present method of estimating reliability is based on the intercorrelations of individual test items with the test as a whole. The magnitude of the sample r_{xx}'s indicates that the items were quite uniform as measures of the instructional objectives.

In concluding the chapter on the results of the statistical data, consideration is given to the probability of false rejection of hypotheses.

In the present study there are the equivalent of 32 hypotheses. Kirk (1968) has pointed out that:

> If an experimenter makes C independent [italicized in original] comparisons among means the probability of obtaining at least one significant comparison by chance.... is approximately equal to Cα for small values of α. Therefore, as the number of independent comparisons increases the probability of at least one spuriously significant result also increases. (Kirk, 1968, pp. 77-78)

Of the 32 hypotheses, the first 16 involve comparisons of means. Hypotheses nos. 1a through 4b involve two comparisons each, totaling 16, and hypotheses nos. 5a through 8b involve 8 comparisons; total 24 comparisons. Hypotheses nos. 9a through 16b involve correlation computations and the significance of each coefficient from zero rho; if these are considered to be comparisons analagous to those described by Kirk (1968) then the grand total of comparisons for the study numbers 40. With α = .01, the probability of spuriously rejecting at least one comparison is approximately four-tenths. By contrast, if α were .05 then at least two of the 40 comparisons would have a probability of false rejection.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

There has been a dearth of studies directed towards organizing and evaluating a cognitive hierarchy of instructional experiences for elementary children based on a major conceptual scientific paradigm and leading to the understanding of the nature of selected physical phenomena. A conceptual model of science of monumental consequence has been the planetary atomic model. It has been described as one of the greatest intellectual achievements of all time because it resulted in classifying the elements of the Periodic Table on the basis of electron structure. As such, it deserves a significant and meaningful place in elementary science curricula.

In the curriculum investigation reported here the planetary atomic model (PAM) was the basis for development of classroom instructional episodes for middle elementary and pre-secondary school children. Though the planetary atomic model (PAM) has been supplanted by more fruitful

models in advanced scientific enterprises it remains as the paradigm for beginning atomic studies. It provides the simplest valid picture on which to build a basic Periodic Table of the elements; it is this reason which has preserved the PAM for introductory instructional purposes.

The objectives for each instructional episode and the instrument to measure pupil attainment of the objectives were derived from hierarchies of cognitive complexity suggested from the literature. The objective of an instructional episode and the measurement of its attainment was given one of four designations: (1) Factual conceptual, background to PAM; (2) Factual-conceptual, pertaining to PAM; (3) Inferential, background to PAM; (4) Inferential, pertaining to PAM.

Episodes designated as background were designed to give pupils experiences in describing, comparing, measuring, predicting, and evaluating the nature of phenomena which cannot be seen or manipulated readily.

It was projected that factual-conceptual background instructional episodes (no. 1, above) would be prelude to

episodes on facts and concepts pertaining directly to the PAM (no. 2, above). Similarly, inferential background episodes (no. 3, above) were projected as prelude to inference-goal episodes relevant to understanding and applying the PAM (no. 4, above). In a cognitive hierarchy the more complex levels may include less complex levels. Hence, an inferential goal may include an aspect that was factual, or conceptual, or factual-conceptual.

Overall, a sequence of classroom episodes about the PAM was developed within a cognitive hierarchy and tested for feasibility with middle elementary and pre-secondary pupils.

A series of jury validations was employed to check content accuracy and also judge correspondence of instructional goals to measurement goals. Directions to the jury of validators are recorded in Appendix A.

The instructional episodes were taught by the regular teachers who were trained by the investigator. The collection of instructional episodes is recorded in Appendix C.

The measurement instrument was a 48 question multiple choice test with four options per item. The reading level of the test was established at the middle elementary level

by reference to a standard fourth grade word list and from examination by a reading specialist. Except for stragglers, the test in pre and post instructional forms was read to the pupils by their own teachers. The items in the pre-instructional form were partially randomized. In the post-instructional form the sequence of items paralleled the instructional sequence. A copy of the measurement instrument is presented in Appendix E.

A fourth grade pilot run at the campus school, State University College at Cortland, resulted in modifications of the instructional episodes and a reduction in the number of items. Pilot instruction was performed largely by the regular teacher, who is not a science specialist. Attainments of the pilot pupils were encouraging. Pilot data are reported in Appendix B.

The experimental run was performed in the spring of 1969 in the Moravia, New York elementary school. Moravia is located in the central part of the state and its clientele is largely from a rural setting.

The data were obtained from eight classes, four of which were reference ("control") classes in each of 3rd, 4th (middle elementary), 5th and 6th (pre-secondary) grades. Reference and experimental classes had been organized at

the beginning of the school year on the basis of similar scholastic achievement; all children had demonstrated normal progress with age peers. Reference classes were selected from the same pool of teachers who volunteered for the experiment. The reference classes received no special instruction, but went on with their regular science program. They were subjected to the same sequence of pre and post instructional testing as the experimental classes. The purpose of reference classes was to make an approach to randomization of class selection, and to provide a check on cognitive gains that might accrue which could be attributed to casual effects or maturation during the seven week tenure of the experiment.

The episodes were taught in 30-45 minute intervals on a nearly daily schedule under regular school conditions.

The teachers of the experimental classes received approximately twelve hours of training by the investigator. They received a professional consultant's fee for the extra work required. The cost of purchasing and preparing the bulk of the instructional materials was borne by the Finger Lakes Region Supplementary Education Center, a Title III agency of the U. S. Office of Education.

The statistical analyses were built around hypotheses relevant to attainments on the four objectives of instruction by grade level, sex, and pre and post instructional measurements.

For hypotheses nos. 1a through 4b variance analysis was used to evaluate the significance of means of experimental versus reference classes on pre and post instructional attainments for each of the four objectives by grade category.

For hypotheses nos. 5a through 8b variance analysis was used to evaluate the significance of means of experimental boys versus girls on post-instructional attainments of the objectives by grade category.

For hypotheses nos. 9a through 16b product-moment correlation and the t test for the significance from zero of the population correlation coefficient was used to evaluate the association between IQ by grade category and sex versus attainments on each of the four objectives. IQ was T-scaled because it was necessary to draw measures of mental ability of the pupils from several standard sources. The program for IQ to T-scale conversion is reported in Appendix D.

An estimate of test reliability from the experimental

run was calculated using the Kuder-Richardson formula for internal consistency; supporting data are reported in Appendix F, and summarized in Table XLIV.

A summary and conclusions relevant to the statistical assessment follow; designations of class or grade category refer to experimental groups except where noted otherwise:

1. Hypotheses nos. 1a through 4b: At $\alpha = .01$, experimental versus reference classes in both grade categories displayed no significant differences in pre-instructional means on any of the objectives of instruction. Assessment of post-instructional means of experimental versus reference classes for each instructional objective in both grade categories, indicates there are differences favoring the experimental groups that range from marked significance to very highly significant.

There is no appreciable evidence to indicate that maturation or casual accruals could be factors in accounting for the magnitude of gains.

2. Hypotheses nos. 5a through 6b: At the middle elementary grade category no significant difference ascribable to sex was measured for any of the four goals of instruction. There appears to be little evidence to indicate that the large gains made by the 3rd and 4th grade children in the experimental program can be attributed to one sex more than the other.

3. Hypotheses nos. 7a through 8b: At the pre-secondary grade category there was a significant difference favoring boys on the factual-conceptual background goal. No appreciable difference ascribable to sex was measured on the remaining three goals of instruction.

Trend analysis was not included in the design of the study, nevertheless it is noted that pre-secondary girls' mean scores on all goals measured lower than the boys'; this apparent attenuation of performance may possibly suggest that a relatively unsuccessful experience at a lower level (e.g., factual-conceptual, background) of the hierarchy of cognitive objectives diminishes (but does not necessarily preclude) success at more complex levels. If such a surmise has validity, then it would lend support to the assumption that the hierarchal concept extends from theory into practice. However, the achievement of the pre-secondary girls could also be attributed to samples that have unresolved spurious factors, and/or to science interests that diverged from those of their male classmates.

Sex differences favoring boys often have been noted in reporting achievement in secondary physical science and mathematics. The earlier emergence of puberty in pre-secondary girls may be expressed in interests that were not met in the experimental program. In the middle elementary experimental group, the girls scored as well as the boys,

and, in general, this group scored better than the older children.

The unexpected general attenuation of the pre-secondary group attainment may be partly explained by an event described in the latter part of chapter no. 3. Moreover, the fifth grade experimental class did not score as well, in general, as any other experimental class. These events have not been subjected to further analysis. In view of the gains reported herein, any possible statistical significance linked to circumstances of a local nature would do little for adjudging the general feasibility of a conceptual schemes science curriculum.

4. Hypotheses 9a through 16b: At $\alpha = .01$ there was no significant correlation measured between IQ by sex and grade category for any of the four instructional objectives. If IQ is acknowledged to have some utility in categorizing pupils for various school enterprises, then it is suggested that there is virtually no evidence from the present study to indicate that success in the program is limited to a narrow range of scholastic ability.

5. According to Tate (1966) the method of estimating test reliability by means of applying a formula for internal consistency, as in the present study, tends to somewhat underestimate the reliability coefficient as found by other methods. It is inferred from the magnitude of the estimated

index of test reliability, .7711 for the experimental run and .8573 for the pilot run, that the test items were quite consistent as measures of the instructional objectives.

6. In settings analogous to the one in the study there is evidence that highly significant attainments are feasible as early as the middle elementary years among boys and girls with a rather wide range of measured ability. Ausubel's (1965) misgivings about the efficacy of a conceptual schemes curriculum for elementary science seem less tenable in light of evidence from the present investigation and the preliminary evidence from the COPES program.

Several recommendations are tendered, resulting from the implementation and assessment of the conceptual schemes elementary science curriculum reported herein:

1. The investigator was given unsolicited testimony from the experimental teachers that the program was well received. For example, all experimental teachers planned to continue using it and at least one reference class teacher planned to initiate it. However, formal assessment of outcomes has been at the cognitive level. It would be of interest to investigate possible long-term influence among children who receive conceptual schemes instruction, regarding their career orientation, effective personal adjustment, and attitudes toward scientific enterprises, in general.

2. In a pilot study, The Conceptually Oriented Program

in Elementary Science (COPES 1967 and 1968) employed the conceptual scheme of energy conservation as the basis for an investigation. The COPES pilot was taught by specialists. The present study and the COPES study have both demonstrated the practicability of a conceptual schemes curriculum, at least in certain elementary school situations. In addition, the present study has demonstrated that regular classroom teachers can successfully convey the instructional format.

An expanded study has been announced by COPES (1969 and 1970) in which a spiral approach is to be applied to development of a complete conceptual schemes science curriculum. The COPES staff has begun preparing materials for presentation by other than specialists. Trial and assessment is in process.

Elementary teachers are not likely to embark upon a conceptual schemes science curriculum on their own volition as a result of taking conventional science teaching methods courses or science courses. For many years to come there will not be a sufficient number of specialists to serve all the elementary schools that may want to expand or revise their science programs.

It is submitted that the program has demonstrated its applicability for training regular classroom teachers with varied science backgrounds. For example, three of the experimental teachers had at least one course in physical science at the college level while the fourth teacher had none, either

in college or during her high school days over 35 years ago. Preparation for teaching the experimental curriculum took place in a semi-laboratory setting and was directly oriented to applying the content and methods described in the instructional episodes. It is recommended that other modes or adjuncts to teacher training be investigated, including the use of single-concept films, tapes, programmed texts and closed circuit television.

3. The cost of equipping the classes for demonstration and individual pupil activities was approximately $100 per class, not including time for typing and art work, nor the teachers' consultation fees. Little additional expense would be necessary for materials for an indefinite period because most of the items are consumed slowly. If the conceptual schemes approach to curriculum development has a desirable long-range effect then it is recommended that a cost comparison with contrasting curricula would be worthy of investigation.

4. Are there experiences in discovery or problem solving curricula which a conceptual schemes curriculum uncovers, enhances, or even suppresses? The measurement for a study devoted to ascertaining the degree of association between contrasting science curricula might be achieved, in part, with the Tabs Test of Scientific Inquiry, developed and validated by Jones (1966).

5. A wide range of socio-economic backgrounds were represented in the classes available for the experiment. However, racial and ethnic differences were not a factor in daily school life. If a conceptual schemes science curriculum has widespread and relatively lasting values, factors of implementation should be investigated in schools with a mixed racial-ethnic population.

6. There was no significant correlation measured between an index of mental ability and cognitive attainments. It is recommended that for purposes of prediction, factors that compose mental ability should be investigated for their degree of association with the goals of the present study. For example, factors such as ability to interpret spatial relations and ability with symbolic and mathematical abstractions could be compared as co-variables with the four objectives of the program reported herein.

7. It is proffered that elementary science curriculum feasibility investigations should be initiated for other conceptual schemes. These might include: the kinetic-molecular principle; wave and particle manifestations of matter and energy; mathematical and physical models applicable to phenomena in astronomy, geology and biology; and the gene principle of heredity.

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APPENDIX A

Directions to the Jurors

RATING SHEET FOR ASSESSMENT OF INSTRUCTIONAL EPISODES

1st Jury Validation

Background

There is a dearth of studies that are directed toward organizing and evaluating appropriate classroom activities for elementary children, which make use of a major conceptual scientific paradigm or model. A conceptual model of science that has had monumental consequence is the Bohr-Rutherford atomic model, or planetary atom. Though it has been supplanted in advanced scientific enterprises, the planetary model is universally employed as an introductory instructional paradigm in atomic studies. The planetary atomic model led to the classification of all the elements by their electron complement in the Periodic Table; this outcome has been described as one of the greatest intellectual achievements of all time. As such it deserves a significant and meaningful place in elementary science curricula.

The Study

The purpose of the present study is to evaluate the following general hypothesis; a major conceptual scheme of science, the planetary atomic model, can be the basis of instructional episodes for pupils of middle elementary and pre-secondary classes.

The instructional episodes have been compiled and modified from a number of sources which include curricula handbooks, commercial sourcebooks, and even college textbooks. As a judge of the suitability of the instructional episodes you are asked to consider three aspects of each of them. Aspect No. 1 is described on pages 1-4. Aspects No. 2 and No. 3 are described on page 4.

Aspect No. 1

Each episode is labeled with a title which indicates its instructional objective(s), namely, FACTUAL and/or CONCEPTUAL, or INFERENTIAL, or FACTUAL-CONCEPTUAL-INFERENTIAL. The titles are described and assumed examples given below.

The aspect to consider: <u>Does the instructional episode fit the purpose implied by its title in any useful operational sense for pupils in both middle elementary and pre-secondary classes</u>?

The objective of an episode entitled FACTUAL:

The objective of factual instruction is a change in behavior which has as its outcome

knowledge of an event or phenomenon, or assumption, or principle. A pupil's attainment will be measured by his ability to recognize correct factual information embodied in the answers of multiple choice test questions.

The objective of an episode entitled CONCEPTUAL:

The objective of conceptual instruction is a change in behavior which has as its outcome the internalizing of an idea or generalization that links facts together in terms of abstracted properties such as color, position, number (ordinal, cardinal), degree or type of change, etc. A pupil's attainment will be measured by his ability to recognize correct conceptual information embodied in the answers of multiple choice test questions.

The objective of an episode entitled INFERENTIAL:

The objective of inferential instruction is a change in behavior which has as its outcome the ability to arrive at a decision or tentative conclusion, or the acceptance of a seemingly incontrovertible outcome based upon a mental model without substantial physical evidence, but from reasoning, partial evidence and relevant facts (the existence of potential energy can only be inferred.... the proof of such occurs when the energy is released). A pupil's attainment will be measured by his ability to recognize a correct inference which explains a physical event, embodied in the answers of multiple choice test questions.

The objective of an episode entitled FACTUAL-CONCEPTUAL-INFERENTIAL:

The objective of factual-conceptual-inferential instruction is a change in behavior which has as its outcome the ability to apply facts and concepts presented during the episode in question and, in part, earlier episodes to make inferences about the nature of selected physical phenomena. A pupil's attainment will be measured by his ability to recognize a correct inference

embodied in multiple choice test items; the test question will describe a new or modified situation to which the pupil will apply the most likely inference.

Assumed example of a FACTUAL activity within an instructional episode:

Pupils observe that a body charged negatively is attracted to a body charged positively. A summary discussion leads them to the tentative conclusion that oppositely charged bodies tend to attract each other.

Assumed example of a CONCEPTUAL activity within an instructional episode:

Pupils observe that the leaves of an electroscope diverge to a greater degree under the influence of an ebony rod that has been rubbed vigorously with fur, than from one which has been rubbed in a less vigorous manner. A summary discussion leads them to the tentative conclusion that electrostatic effects increase where an increase of work has been applied to creating the effect.

Assumed example of a FACTUAL-CONCEPTUAL activity within an instructional episode:

Basic facts about general atomic structure are brought together to build the concept of orderly atomic structure of the elements. The instructor lectures briefly on the form and structure of the basic planetary atomic model, starting with hydrogen. He uses the overhead projector or chalkboard to diagram the buildup of several light elements, giving the rules for electron orbit complement. The pupils do likewise; then they use a simple table of atomic characteristics to draw planetary atomic representations of many of the first 20 elements.

Assumed example of an INFERENTIAL activity within an instructional episode:

An apparent incongruity is the basis for a discussion about possible mechanisms which might be inferred to explain the discrepancy. After the concept of the simple planetary atomic model seems well accepted by the pupils, the instructor presents to them a problem; multi-protonic nuclei should be flying apart due to

electrostatic repulsion. He leads a discussion in which the pupils evaluate their own hypotheses in attempting to explain the seeming incongruity.

Assumed example of a FACTUAL-CONCEPTUAL-INFERENTIAL activity within an instructional episode:

The assumed example of a FACTUAL-CONCEPTUAL activity is extended to include interpretation of a simplified version of the Periodic Table of the elements. The pupils are then asked to make inferences about certain characteristics of elements for which only blanks appear in the Table.

Aspect No. 2

Are the instructional activities in this episode scientifically and technically sound from the standpoint of a simple planetary atomic model and the limits implied in the description?

Aspect No. 3

Based upon your experience, actual or extrapolated, has the episode ANY redeeming value for inclusion in a sequence of instructional experiences on the planetary atomic model for both middle elementary and pre-secondary pupils?

(if you judge it suitable for pre-secondary, but absolutely impossible for middle elementary mark it "no".)

ADDITIONAL CRITERIA AND INFORMATION RELEVANT TO ASSESSING THE EPISODES

1. In your decisions, do not give major emphasis to possible language problems. The episodes accepted from the present validation process will be subject to further assessment and to the scrutiny and criticism of the teachers who will present the activities to their own classes.

2. All episodes which are accepted will be taught to all experimental classes that comprise the two major grade categories for the study, namely, middle elementary (grades 3 and 4) and pre-secondary (grades 5 and 6).

3. An effort has been made to choose episodes and modify them so that pupil-teacher interaction is maximized. The most common method of instruction for the episodes will be discussions which include lecture-discussion, demonstration-discussion, and short laboratory-type activities followed by discussion. Several episodes have provision for reinforcement activities.

4. Several episodes carry the sub-label entitled "background". Their purpose is to give the pupils preliminary experiences in dealing with unseen factors or entities.

5. Several episodes relate to findings or evidence that postdate initial development of the planetary atomic model. This in no way confounds the purposes of the activities as a whole because a rigorous planetary atomic model is not being employed, nor is it limited to knowledge at a certain point in time. For example, the neutron was "uncovered" a number of years after the major postulates relevant to the planetary atomic model were introduced.

6. Certain aspects* of the validity of each of 25 proposed classroom instructional episodes are in question. You are asked to judge the content and purpose of the proposed episode in respect to the several stated aspects*. Your judgment and that of others will be compiled to obtain an assessment for each episode. A sample rating sheet is presented on page no. 6. An individual rating sheet is provided on the page following each episode. The items on the rating sheet coincide with the stated aspects*.

*described on pages 1-4, herein.

RATING SHEET, INSTRUCTIONAL EPISODE NO._____

Aspect I A) Does the episode fit the purpose implied by its title (FACTUAL, CONCEPTUAL, or INFERENTIAL, or a combination of these) in any useful cognitive sense for pupils in both middle elementary and pre-secondary classes?

yes_____no_____if no, please proceed to part "B".

Aspect 1 B) If IA was marked "no", please check which one of these best describes this episode using the criterion in IA.

FACTUAL?_____
CONCEPTUAL?_____
FACTUAL-CONCEPTUAL?_____
INFERENTIAL?_____
FACTUAL-CONCEPTUAL-INFERENTIAL?_____
OTHER?_____please comment

Aspect 2. Is the episode scientifically and technically sound from the standpoint of a simple atomic model and the limits implied in the described activities?

yes_____no_____comment (optional)

Aspect 3. Based upon your experiences (actual or extrapolated) has the episode ANY redeeming value for inclusion in a sequence of instructional experiences on the planetary atomic model for both middle elementary and pre-secondary pupils?

yes_____no_____comment (optional)

RATING INFORMATION FOR ASSESSMENT OF PROPOSED MEASUREMENT INSTRUMENT FOR CERTAIN INSTRUCTIONAL EPISODES

2nd Jury Validation

There is a dearth of studies that are directed toward organizing and evaluating appropriate classroom activities for elementary children, which make use of a major conceptual scientific paradigm or model. A conceptual model of science that has had monumental consequence is the Bohr-Rutherford atomic model, or planetary atom. It has been described as one of the greatest intellectual achievements of all time because it resulted in classifying the elements of the Periodic Table on the basis of electron structures. As such, it deserves a significant and meaningful place in elementary science curricula.

A set of classroom instructional episodes involving a simplified planetary atomic model has been produced. Each episode has been labeled and subsequently validated by an expert jury as to instructional objective, namely, factual, conceptual, inferential, or a combination of these objectives. A pre and post instructional multiple choice test is being prepared.

Included herein are the test items that may be included in the instrument which measures pupil attainments after classroom presentation of the instructional episodes. You are asked to judge (and if time permits, briefly comment upon) two factors of each test item.

Factor I

Is the science content of each item technically sound? In items that refer to atomic structure or characteristics, the atomic model referred to is a non-rigorous planetary model as commonly used in introductory or vocational studies of the atom.

Factor II

Aside from the specialized* vocabulary which will be introduced during the period of instruction, does the phraseology and its organization in the test item seem suitable for middle elementary pupils? Each word, other than the specialized ones*, has been checked against a list that 4th graders can reasonably be expected to read. The emphasis, in judging the readability of the whole item, should be upon simplicity of phrasing, rather than simplicity of individual words.

*specialized in reference to the studies in atomics.

You are asked to indicate your opinions in the following ways:

Factor I
(scientifically or technically sound?)

If the item is judged satisfactory, make no mark. If the item is judged unsatisfactory write over the identification number with an "X". It would be appreciated if you would describe or indicate, in brief, the nature of an objection, if time permits.

Factor II
(overall phrasing simple enough for middle elementary levels?)

If the item is judged satisfactory, make no mark. If the item is judged unsatisfactory, write over the identification number with an "O". It would be appreciated if you would describe or indicate, in brief, the nature of an objection, if time permits.

Additional Information...

1. The items have been organized in a certain serial order. Some of the original items have been eliminated and therefore the serialization has gaps.

2. The early items labeled "background" are derived from instructional episodes which are planned to involve the pupils in experiences in making inferences about the nature of unseen entities. The "background" test items do not necessarily refer directly to a planetary atomic model.

3. Each item's identification number is followed by one of these words or phrases: FACTUAL, and/or CONCEPTUAL, and/or INFERENTIAL; these designations are not to be considered at the present stage of validation.

4. Some items are headed by either of two directions to the pupil, PUPIL USES TABLES, or PUPIL MAY USE TABLES. These tables refer to (1) a list of the basic atomic characteristics of the first 20 elements, and (2) a simple Periodic Table of the Elements.

ASSESSMENT OF TEST ITEMS AS MEASUREMENTS OF THE OBJECTIVES OF CERTAIN INSTRUCTIONAL EPISODES

3rd Jury Validation

Background

There is a dearth of studies that are directed toward organizing and evaluating appropriate classroom activities for elementary children, which make use of a major conceptual scientific paradigm or model. A conceptual model of science that has had monumental consequence is the Bohr-Rutherford atomic model, or planetary atom. It has been described as one of the greatest intellectual achievements of all time because it resulted in classifying the elements of the Periodic Table on the basis of electron structures. As such, it deserves a significant and meaningful place in elementary science curricula.

The Study

A set of classroom instructional episodes involving a simplified planetary atomic model has been produced. Each episode has been labeled and subsequently validated by an expert jury as to instructional objective, namely, factual, conceptual, inferential, or a combination of these objectives. The episodes are to be taught to a pilot class in the SUC Cortland Campus School. A pre and post instructional multiple choice test is being prepared as the measuring instrument for the study. The science content and readability of the proposed test items were validated by an expert jury. In the present stage of validation you, the reader, are being asked to serve as a juror to decide if the stated behavioral objective of each episode is measured by specific test items.

Analysis of the pilot results will lead to modification of the instructional episodes and the test.

For the experiment, 8 classes, apart from the pilot will be sought two each in grades 3, 4, 5, 6. These will provide an experimental and reference class in each of two categories, middle elementary (3 and 4) and pre-secondary (5 and 6). The teachers of the pilot and the experimental groups are to be trained by the investigator. All classes are to be instructed by their regular teachers.

The Validator's Task

Each description of an instructional episode has a lead paragraph giving a specific behavioral objective or goal. The validator is asked to judge whether or not the stated behavioral goal is measured by the multiple choice test item(s) attached to each episode description.

The proposed test items are designed, hopefully, to assess the pupils' ability to recognize, recall, and, in certain cases, apply the facts, concepts and inferences which are the objectives of the instruction.

The validator should read the episode and its proposed test items; he should re-read the goal stated in behavioral terms in the episode, then he should decide if each test item that is proposed for an episode is a measure of the stated goal(s) of that episode. If a test item does not appear to be a measure of the goal(s), please mark that item's identification number with an "X"...do the same for borderline decisions. If the validator has time, it would be greatly appreciated if brief comments accompanied negative decisions. Please write such comments on the test item sheet. Make no mark for items that are acceptable.

Additional Information

1) Some episodes have more than one goal, or the goal is divided into parts. There should be at least one test item for each goal or sub-goal. The validator might decide that some portion of plural goals or sub-goals is not met by extant test items. If so, a brief comment would be appreciated, as would comments that suggest additions and modifications to the test items.

2) The test items labeled "background" are derived from episodes which are planned to involve the pupils in experiences relevant to the nature of unseen entities. The background episodes and, hence, the "background" test items do not necessarily refer to a planetary atomic model.

3) Some of the proposed items are headed by either of two directions to the pupil, PUPIL USES TABLES, or PUPIL MAY USE TABLES. These directions refer to:

   a) A list of the basic atomic characteristics of the first 20 elements...see the first page of tentative episode no. 10.

   b) A simple Periodic Table of the elements...see the 9th and 10th pages of tentative episode no. 13.

ASSESSMENT OF TEST ITEMS AS MEASUREMENTS OF THE OBJECTIVES OF CERTAIN INSTRUCTIONAL EPISODES

4th Jury Validation

Background

There is a dearth of studies that are directed toward organizing and evaluating feasible classroom activities for elementary children which make use of a major conceptual scientific paradigm or model. A conceptual model of science that has had monumental consequence is the Bohr-Rutherford atomic model, or planetary atom. It has been described as one of the greatest intellectual achievements of all time because it resulted in classifying the elements of the Periodic Table on the basis of electron structures. As such, it deserves a significant and meaningful place in elementary science curricula.

The Study

A set of classroom instructional episodes which lead to and include a simplified planetary atomic model has been produced. Each episode has been labeled as to instructional objective, either factual-conceptual, or inferential. The labeled objective of each episode has been validated by an expert jury. A pre and post instructional multiple choice test has been prepared as the measurement instrument for the study. Test items are associated with instructional episodes by labeled instructional objective and by the same identification number. In an earlier stage of validation an expert jury evaluated the association between episode and test item(s), by objective.

The episodes have been taught to several classes by their own teachers, and the test was administered. Results have been analyzed, and certain modifications have been incorporated in the test. In the present stage of validation you are being asked to decide if the test item(s) for each episode remain properly labeled for the instructional objective they purport to measure.

The objective of an episode entitled FACTUAL-CONCEPTUAL

> The objective of factual instruction is a change in behavior which has as its outcome knowledge of an event or phenomenon, or assumption, or principle. The objective of conceptual instruction is a change in behavior which has as its outcome the internalizing of an idea or

generalization that links facts together in terms of abstracted properties such as color, position, number (ordinal, cardinal), degree or type of change, etc. A pupils's attainment will be measured by factual and/or conceptual information embodied in the answers of multiple choice test questions.

The objective of an episode entitled INFERENTIAL or FACTUAL-CONCEPTUAL-INFERENTIAL

The objective of inferential instruction is a change in behavior which has as its outcome the ability to arrive at a decision or tentative conclusion, or the acceptance of a seemingly incontrovertible outcome based upon a mental model without substantial physical evidence, but from reasoning, partial evidence and relevant facts (the existence of potential energy can only be inferred.... the proof of such occurs when the energy is released). The objective of factual-conceptual-inferential instruction is a change in behavior which has as its outcome the ability to apply facts and concepts presented during the episode in question and, in part, earlier episodes to make inferences about the nature of selected physical phenomena. A pupil's attainment will be measured by his ability to recognize a correct inference embodied in multiple choice test items; the test question may describe a new or modified situation to which the pupil will apply the most likely inference.

Assumed example of a FACTUAL-CONCEPTUAL activity within an instructional episode:

Basic facts about general atomic structure are brought together to build the concept of orderly atomic structure of the elements. The instructor lectures briefly on the form and structure of the basic planetary atomic model, starting with hydrogen. He uses the overhead projector or chalkboard to diagram the buildup of several light elements, giving the rules for electron orbit complement. The pupils do likewise; then they use a simple table of atomic characteristics to draw planetary atomic representations of many of the first 20 elements.

Assumed example of a FACTUAL-CONCEPTUAL-INFERENTIAL or INFERENTIAL activity within an instructional episode:

The assumed example of a FACTUAL-CONCEPTUAL activity is extended to include interpretation of a simplified version of the Periodic Table of the elements. The pupils are then invited to make inferences about certain characteristics of elements for which only blanks appear in the Table.

The Validator's Task

The validator should read each instructional episode and the test question(s) following it. He should then decide if the episode's instructional objective, labeled either factual-conceptual or inferential*, is measured in the cognitive sense described on pages 1 and 2 by the test item(s).

Attainment on an episode labeled inferential which is measured by more than one test item may include some items at a lower level of the cognitive hierarchy than the inferential level. Thus it is possible that an episode labeled inferential* may have attached to it one or more test items at the factual-conceptual level in addition to one or more at the inferential level.

For negative decisions a test item's identification number should be marked with an "X". If time permits, a brief note of explanation would be helpful, and appreciated. Mark "O.K." for acceptable items.

Additional Information

1) There are 48 questions distributed for 14 instructional episodes.

2) The test items labeled "background" are derived from episodes which are planned to involve the pupils in experiences with the nature of unseen entities. The background episodes and, hence, the background test items do not necessarily refer to a planetary atomic model.

3) Some of the proposed test items are headed by either of two directions to the pupil, PUPIL USES TABLES, or PUPIL MAY USE TABLES. These directions refer to:

   a) A list of the basic atomic characteristics of the first 20 elements... see the 5th page of episode no. 11.

   b) A simple Periodic Table of the elements... see the last pages of episode no. 14.

*or factual-conceptual-inferential

APPENDIX B

Data from Pilot Run

Appendix B, Table No. 1

Pilot Class: Significance of Difference Between Pre and Post Instructional Means by Sex for Each Instructional Objective; 12 Boys, 9 Girls

Instructional Objectives	No. of Test Items	Sex	Pre-Instructional Mean	Pre-Instructional Standard Deviation	Post-Instructional Mean	Post-Instructional Standard Deviation	Standard Error of Difference Between Post & Pre Means	t Ratio	Is Gain Significant at $\alpha = .01$?*
Fac-Conc., Background	4	Boys	1.4166	1.4795	2.8333	1.0299	.43761	3.2373	Yes
		Girls	.5555	.7264	1.5555	1.0138	.37273	2.6833	No
Fac-Conc., PAM	12	Boys	2.4166	.9962	5.0000	5.2223	.69982	3.6914	Yes
		Girls	3.3333	.8660	4.6667	2.7839	.89765	1.4855	No
Inferential, Background	16	Boys	5.0000	1.4142	6.9166	3.0289	1.15962	1.6528	No
		Girls	4.8889	1.0543	7.5555	1.7401	.40826	6.5318	Yes
Inferential, PAM	16	Boys	2.9166	.9004	8.4166	3.8954	1.18526	4.6403	Yes
		Girls	2.7778	1.5635	9.1111	3.0596	1.09304	5.7825	Yes
	48								

*One-tailed test: degrees of freedom; boys = 11, girls = 8.

Item Analysis of Test

Revisions of the measurement instrument, resulting from analysis of the pilot class performance, are summarized in Table No. 2, Appendix B.

In certain cases an item was retained with revision, even though in the original form the item discriminated poorly between high and low scorers and/or the difficulty index was low or high. Items that were revised or dropped were done so as a result of interviews with high-scoring children and the teacher.

All of pilot episode no. 14 was dropped because of difficulty expressed by pupils and teacher with the concepts of electron energy levels to account for certain phenomena associated with spectral color and x-rays. The most basic limiting factor appeared to be that the activities did not provide enough preparation in the conservation principle. In addition, simple, direct demonstration materials were not commercially available, nor could they be developed with the time and money available. In the future it may be possible to bring aspects of these important ideas to elementary classrooms, via short cartoon-type films coupled with programmed worksheets.

In the table the column entitled Decision is coded thusly:

M = Slight modifications were made in works, phrases, diagrams, or placement order in the test booklet.

R = Heavy revisions were made to retain context of the subject matter.

D = Drop.

Appendix B, Table No. 2

Pilot Class: A Summary of Item Analysis from the Pilot Post-Instructional Measurement Instrument and the Item Distribution for the Experimental Run: N=21 Pupils

Item No. Pilot Class	Item Difficulty, Percent Correct	Upper 27% of Class	Lower 27% of Class	r_b* Index of Item Discrimination or Validity	Decision*	Item No. for Experimental Run
		Factual-Conceptual; Background Items, n=4				
7.1	67	83	50	.37	M	7.1
7.2	48	50	50	.00	R	7.2
7.3	81	100	50	.68	M	7.3
7.4	33	50	17	.37	M**	7.4
		Factual-Conceptual; PAM Items, n=12				
9.1	29	67	17	.51	M	9.1
9.2	14	17	17	.00	R	9.2
9.3	57	100	50	.68	M	9.3
9.4	29	33	0	.57	M	9.4
12.1	57	100	17	.84	-	12.1
12.2	52	83	00	.83	-	12.2

(continued)

Item No. Pilot Class	Item Difficulty, Percent Correct	Upper 27% of Class	Lower 27% of Class	r_b= Index of Item Discrimination or Validity	Decision*	Item No. for Experimental Run
Factual-Conceptual; PAM Items, n=12 (continued)						
12.3	43	83	00	.83	-	12.3
12.4	48	83	17	.64	M	12.4
12.5	43	50	33	.18	R	12.5
13.1	48	50	33	.18	M***	13.1
13.2	33	33	33	.00	R***	13.2
13.3	33	67	00	.76	M***	13.3
Inferential; Background Items, n=16						
1.1	90	100	83	.44	M	1.1
2.1	43	33	00	.57	M	2.1
3.1	33	83	00	.83	-	3.2
3.2	76	100	83	.44	M	3.1
4.1	14	17	00	.42	M	4.1
5.1	48	83	33	.50	M	5.1
5.2	67	100	67	.59	M	5.2

(continued)

Item No. Pilot Class	Item Difficulty Percent Correct	Upper 27% of Class	Lower 27% of Class	r_b = Index of Item Discrimination or Validity	Decision*	Item No. for Experimental Run
		Inferential; Background Items, n=16 (continued)				
5.3	19	00	33	Neg. Correlation	R	5.3
6.1	86	83	83	.08	D	---
6.2	33	67	00	.76	-	6.1
6.3	19	50	00	.69	M	6.2
6.4	38	17	00	.42	M	6.3
8.1	62	100	67	.59	M	8.1
8.2	38	83	17	.64	M	8.2
8.3	67	67	67	.00	R	8.3
8.4	43	83	33	.50	M	8.4
8.5	29	17	00	.42	M	8.5
		Inferential; PAM, n=16				
10.1	38	50	33	.18	R	10.1
11.1	67	83	33	.50	M	11.2****
11.2	33	83	17	.64	M	11.3

(continued)

Item No. Pilot Class	Item Difficulty Percent Correct	Upper 27% of Class	Lower 27% of Class	r_b = Index of Item Discrimination or Validity	Decision*	Item No. for Experimental Run
		Inferential; PAM, n=16 (continued)				
11.3	81	100	33	.76	-	11.4
11.4	48	83	50	.37	M	11.5
11.5	67	83	33	.50	M	11.1****
11.6	90	100	67	.59	M	11.6
11.7	81	100	50	.69	-	11.8
11.8	62	100	33	.76	-	11.7
14.1	76	100	50	.69	D	----
14.2	71	100	33	.76	D	----
14.3	24	33	17	.21	D	----
14.4	33	33	33	.00	D	----
15.1	48	67	67	.00	R	14.2****
15.2	62	100	17	.83	-	14.1****
15.3	43	67	17	.50	M	14.3
15.4	10	33	00	.57	M	14.4
15.5	48	83	33	.50	M	14.5

(continued)

Item No. Pilot Class	Item Difficulty Percent Correct	Upper 27% of Class	Lower 27% of Class	r_b = Index of Item Discrimination or Validity	Decision*	Item No. for Experimental Run
		Inferential; PAM (continued)				
15.6	52	67	67	.00	R	14.6
15.7	43	67	17	.50	M	14.7
15.8	19	17	17	.00	D	----

*M = modify; R = revise; D = drop

**The investigator discovered a content ambiguity after jury validation and administration to the X and R classes. The ambiguity is described and the treatment noted on the first page of Appendix E.

***Based on the validator's judgment, nos. 13.1, 13.2 and 13.3 were changed from inferential on the pilot run to factual-conceptual on the experimental run. Data for the pilot run were rendered on the same basis as for the experimental run.

****Placement of the item was changed in the test booklet.

APPENDIX C

Sequence of Instructional Episodes

AN INVESTIGATION IN ELEMENTARY SCIENCE CURRICULUM EMPLOYING A MAJOR CONCEPTUAL SCHEMES APPROACH

Instructional Episodes Leading To
and Pertaining to the Planetary Atomic Model

by

S. Harvey Steinberg

January, 1969
revised July, 1969

EPISODE #1

INFERENTIAL (background)

This instructional episode is designed to give children background experience in accounting for certain physical phenomena in terms of entities that are not seen directly.

At the completion of this instructional episode the pupil should be able to select correct statements relevant to the inference that unseen small spaces exist in the structure of certain substances.

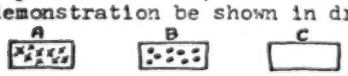
Fill a small beaker with cotton and another beaker of equal size with water. Cram as much cotton in as possible without going over the rim. Use a dropper to transfer the water into the beaker of cotton, and note that the water and cotton eventually seem to occupy the same space. Ask the pupils what may be taking place among smallest bits of cotton and smallest bits of water. During the discussion, the instructor should write the pupils' tentative hypotheses on the chalkboard or overhead projector, then ask the class to evaluate each hypothesis. See summary question no. 2 for the accepted hypothesis. Some children may ask if the process can be reversed, that is, place small bits of cotton into water until the cotton and water seem to occupy the same space. The conclusion is valid both ways.

Summary Questions

1) At normal temperatures nearly all substances (materials) can be grouped by their physical state, solid, liquid, gas. Is cotton a solid or a liquid? [Flexible solid.] Is water as used in this instructional episode a solid or a liquid? [Solids tend to keep a shape, liquids readily take the shape of the bottom of their containers, gasses fill their containers.]

2) Why do we think that the water fills in spaces within the cotton mass? [The cotton can be removed and nearly all of the water wrung from it.]

3) If drawing A represents cotton and drawing B represents water, how would the results of the demonstration be shown in drawing C?



4) How is a sponge able to hold large amounts of liquid?

New Vocabulary

beaker
flexible
materials
represents
substance

EPISODE #2

INFERENTIAL (background)

This instructional episode is designed to give children background experience in accounting for a change in specific matter in terms of effects which are not seen directly.

At the completion of this instructional episode the pupil should be able to select correct statements relevant to the inference that the substance involved is made up of tiny invisible entities or bits which are in motion.

Pour some ammonia or perfume in a shallow dish. Ask pupils to indicate when they first notice the odor as it diffuses through the air in the room. Invite pupils to suggest an explanation for the spread of fumes (gas) across the room. A reasonable assumption is that a little of the substance escapes (or evaporates) into the air. This idea can be tested by exposing a small quantity of rubbing alcohol to air until it disappears, or let alcohol evaporate from the arms of the pupils.

The pupils should be led into a discussion about the conditions that appear to be necessary for the sensing of odors, and for the evaporation of substances. Ask them to hypothesize which of these situations would most quickly permit them to smell something:

A) The air in the room does not move.

B) The air in the room moves, but the bits or molecules* of the substance do not move.

C) The air moves and the bits or molecules of the substance move.

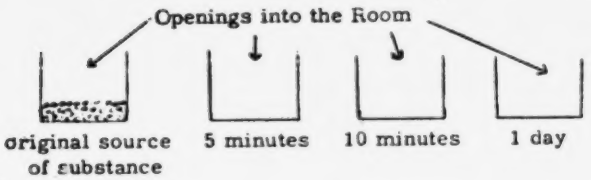
(continued)

*The term molecule is defined more precisely in a later instructional episode. For this episode define molecule as tiny invisible bits or "parts" of the substance.

EPISODE #2 (second of two pages)

Summary Questions

1) If the first drawing shows the substance used in the beginning of the demonstration, fill in the drawings to show the amount of it after the time period indicated.



2) Why does the source substance disappear? Where does it go?

3) Which pupils (as to location) noticed the substance's odor first? Would the results be much different if these same pupils were originally at different locations? How can we be sure?

4) Why can we see the substance at its source, but cannot see the substance as it approaches us? [It changes from a liquid with molecules close together, to a gas with molecules far apart. It is inferred that the molecules are very small, because we can't see them as a gas.]

New Vocabulary

alcohol
ammonia
evaporate
fumes
molecule(s)

EPISODE #3

CONCEPTUAL - INFERENTIAL (background)

This instructional episode is designed to give children background experience in accounting for differential dispersals of a substance in terms of heat associated with it.

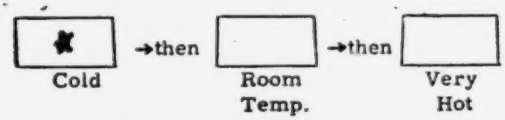
At the completion of this instructional episode the pupil should be able to select correct statements relevant to the inference that the substance involved becomes diffused and the dispersal is dependent on temperature.

Set out three beakers of equal volume. In one beaker put water at room temperature or at the temperature of the cold water faucet. In a second beaker place near-boiling water to a level equal to the water in the first beaker. In the third beaker place two ice cubes and enough cold water to equal the level in the other beakers. Use a dropper to place a few drops of dye solution in each of the beakers, or use a flat wooden splint to put a few particles of powdered dye in each beaker. Ask the pupils to explain what is happening in each beaker. In the ensuing discussion, these hypotheses should be accepted as tenable (1) the dye particles or bits of dye are dispersed or diffused in water, (2) the dispersal per unit of time appears to be dependent on temperature.*

Be sure the pupils understand that the amount of the dye (or dye solution,except for slight evaporation) is conserved... that is, though it spreads out and looks larger, it has done so at the expense of "thickness."

Summary Questions

1) If the first drawing below represents dye solution after 1 minute at cold temperature draw a diagram of the dye solution later on when it warms to room temperature; when it is made very hot.



(continued)

*Pupils may inquire about the possibility of removing sufficient heat to reverse the dissociation of the dye in solution... in other words to make it denser so that the volume decreases. This would require special apparatus which produces temperatures far below the capabilities of common coolants. The volume could not be greatly reduced in any case because of certain "forces" that exist between the particles of the material.

EPISODE #3 (second of two pages)

2) (a) What makes the heated dye solution spread out more rapidly than the cold one?

   (b) Give some examples in everyday life in which heated substances spread out more rapidly than do cooler substances.

3) In an earlier activity the substance could not be seen spreading toward us, but we sensed it by its odor. In the present activity we see the substance spreading; does this show that the bits of dye are in any way different than the bits used in Episode No. 2? Explain. [The bits in Episode No. 2 are each probably smaller than the bits of dye, herein.]

New Vocabulary

Diffusion, Dispersion
Dye
Increase, Decrease

EPISODE #4

FACTUAL - CONCEPTUAL - INFERENTIAL (background)

This instructional episode is designed to give children background experience in accounting for changes in forms of specific matter, in terms of heat associated with it.

At the completion of this instructional episode the pupil should be able to select correct statements relevant to the inference that small, not-easily-seen bits or molecules are kept apart by the heat energy associated with them.

Pour some hot water into a beaker. Place an ice cube on a curved glass dish called a watch glass, and cover the beaker with the glass. Invite the pupils to answer these questions.

1) Liquid is collecting (by condensing) on the lower side of the watch glass. Where does it come from?

2) Look at the area just above the water's surface (higher up the molecules may lose enough energy to come back together as visible vapor before collecting as liquid on the watch glass). Why can't the molecules be seen leaving the surface of the water?

3) On the cold glass, why do the molecules cling together?

The idea to seek from the pupils is that the molecules of water are individually much too small to be seen. However, when the molecules strike the cold glass (why do they travel from the water upward?) something happens and the molecules collect near and on top of one another so that masses of them appear as a fogged portion or film on the glass. Ask the pupils to explain the events observed. [Heat energy or work*, causes the water molecules to increase their motion, until they separate from one another... some fly off into space. When the "fliers" (at high energy) strike the cool (low energy) glass they give up their heat energy to the glass and their energy of motion is reduced; this leads to a tendency** to collect together.]

(continued)

*Energy is defined as the ability to do work. In a subsequent instructional episode, the terms "energy" and "work" will be treated more definitively.

**There is concomitant electrostatic attraction but this idea should not be pursued here.

4) In the process of condensing, do the molecules themselves get smaller, or do the molecules get closer together? How can we be sure?

[Direct evidence is beyond our capabilities. However, it is inferred that the molecules remain the same size but get closer together as they lose the energy that has caused them to stay apart. The inverse phenomena from which this inference is drawn is demonstrated in Episodes no. 2 and no. 3.]

Summary Questions

1) See questions 1-4 above.

2) What is the general effect of heat on molecules as compared to coolness, or loss of heat? [The energy of motion of molecules tends to increase with an increase of heat energy; a loss of heat energy tends to reduce the energy of motion.]

3) Describe several everyday events that can be explained in terms of the instructional experiences herein.

New Vocabulary

condense
decrease
energy
increase
tends, tendency

EPISODE #5

CONCEPTUAL - INFERENTIAL (background)

This instructional episode is designed to give children background experience in making and communicating hypotheses and tests of hypotheses about physical attributes of unseen objects.

At the completion of this instructional episode the pupil should be able to select correct statements referring to: (1) the notions of length, volume, and density as applied to unseen entities in making reasonable estimates about the properties of those entities, and (2) development and testing of mental models of entities whose properties cannot be directly observed.

Activity A

The instructor employs objects of the shapes pictured, then the class is asked to discuss answers to the questions below:

Rectangular (oblong) Cube (square) Sphere Disc (circular) Cylinder Prism (triangular) Pyramid

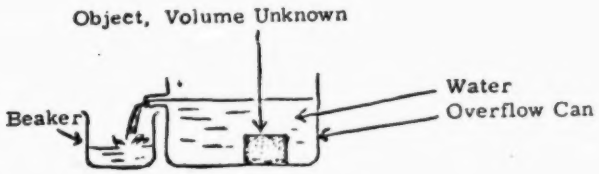
1) Ask the pupils to identify the shapes.

2) Which object(s) would be easiest to push or pull if they all weighed the same? [The round ones]
Why? [Less rubbing]

3) Which object takes up the most volume or space? The least? Use an overflow can as pictured below. The object which makes the most water overflow has the greatest volume. Mark the water level within the beaker by stretching a rubber band around the beaker. Use thin wire tongs to grip and hold down objects that float. Though the wire tong takes up some volume, it is a constant that need not be considered in making the relative measurements, herein. For each measurement be sure the trough is filled up to the level of the spigot and is just ready to commence dripping.

(continued)

EPISODE #5 (second of four pages)



4) If the objects were all made from the same substance, which one would weigh the most? Why?

5) If the biggest object is not the heaviest, what can be inferred about the molecules or particles of which it is composed? [Either lighter, or farther apart, or both.]

Activity B

The processes involved in the following part of the activity are analogous to those that scientists use in discovering the properties of unseen entities such as atoms and their sub-particles.

In each of enough boxes (small cardboard, or cigar boxes) for each pupil there has been placed a common object (pencil, metal strip, spool, wood block, etc.) and the box has been "permanently" sealed. These will be used for the "black box" experiment in which the pupil is to use simple manipulations and then build mental models of the box's contents to infer what is inside. He can never open the box; there is an important analogy here with the conception of the atoms of which the world is made. They cannot be seen...all that can be done is to make mental approximations and models of their structure and test these estimates and revise or extend the mental model as experimental results confirm, deny, or confound the model. One of the most important conclusions is that it can be inferred with great certainty what is most probably NOT in the box, and thus some models can be rejected with great certainty; obviously, there is not a real dog inside a box.

By appropriate manipulation, a pupil should be able to estimate the approximate volume of the object (how much space

it takes up in comparison to the box), density* (weight/volume), and hence, composition of things that cannot be seen. Invite pupils to estimate the density of the object in the box by "comparing" it to the density of familiar objects. For example, is the object more dense, as dense, or less dense than a coin?, a sponge?

Invite certain pupils to check each other's estimates in front of the class...one child describes his estimate of volume, weight, shape, density on a piece of paper and hands it to the teacher. Another child performs "model-thinking" anew with the same box in front of the class. The teacher compares the two "models" for the whole class.

The teacher should ask the pupils to name some entities that cannot readily be seen, but about which much is known. [electricity, atoms, molecules, magnetism, virus, certain diseases, electrons, air.] Point out that the use of the senses, coupled with imagination are common to answer-seeking projects.

Summary Questions

Activity A. See Questions in Activity A.

Activity B.

1) (a) Give four general characteristics of the contents of the box which can be estimated with reasonable accuracy? [Shape, volume, weight, density.]

(b) Can we be sure that a living thing is <u>not</u> in the box?

*To give the pupils more experience with the concept of density, fill a plastic bag with one pound of loose paper and demonstrate that its much greater volume is balanced by a one pound metal object of much smaller volume. Ask the pupils to explain the difference...accept answers that suggest, (1) greater space between the molecules or particles of paper as compared to the particles of metal, and (2) a difference in the ultimate structure of the particles. Separately weigh the two objects using a spring scale. Adjust the contents of the plastic bag to weigh one pound. Use rubber bands around the closed neck of the bag to hook the bag to the spring scale. To fasten the metal object to the scale, wrap rubber bands tautly around the object and attach to the scale hook.

EPISODE #5 (fourth of four pages)

(c) What can be said about the contents of the box with great certainty? Give examples.

(d) Can the contents of the unopened box ever be known for certain without the use of special instruments?

2) (a) Give some examples in which scientists deal with invisible things with confidence. [See examples, given before.]

(b) Do pupils ever deal with invisible things with confidence? How do they know what the results will be if the object(s) can't be seen?

New Vocabulary

cube
cylinder
density
disc
rectangle (rectangular)
prism
pyramid
sphere
square
triangle (triangular)
volume
oblong

EPISODE #6

FACTUAL - CONCEPTUAL - INFERENTIAL (background)

This instructional episode is designed to impart to children background experience about the principle of work and energy transformations to account for a wide range of physical events.

At the completion of this instructional episode the pupil should be able to select correct statements and/or diagrams that relate to: (1) interpretation of the concepts of energy and work, and (2) the inference that energy transformations result from work.

Pair the pupils. One pupil in the pair repeatedly bends a piece of light-weight coat hanger wire. It is flexed with great rapidity until it breaks. As the wire is flexed the other pupil places a finger upon the flexing point to sense the increasing heat produced. Invite them to explain the source of heat. If the pupils use the word "friction", ask them to explain, friction of what, with what? The problem may become clearer if the pupils, after bending their wires, wave them vigorously through the air in an attempt to produce appreciable heat. Of course, the air provides very little frictional resistance. The purpose here is to give pupils experience in inferring that small invisible bits (the term molecule can be substituted here in a somewhat less-than-rigorous sense) of the wire are being moved and separated by an external force. Molecules of the wire are coupled tightly together (how they are coupled is beyond the scope of our studies) and some of the work done to weaken or loosen the couplings shows up as heat. Heat is a form of energy; name other forms such as electrical energy, energy of motion, light energy. Some of the pupils' body chemical energy allowed them to make movements that were ultimately transformed to heat energy in the wire.

Tell the pupils that work (contrast it to common meanings) in science is the measure of energy. For our purposes, the words work and energy can usually be interchanged. Work is defined as force acting through a distance, or which produces movement. A force is manifested as a push or pull. A subtle but important concept differentiates a force which produces movement from a force that is incapable of itself in producing movement. Only the former produces work or energy. [The latter may produce only pressure. However, the potential to produce work, as in a cocked rifle bolt, is termed potential energy. The concepts of pressure and potential energy will not be pursued in our studies.]

(continued)

EPISODE #6 (second of three pages)

Work is capable of transformations. Nearly all appliances in our homes, schools, and industries make energy transformations for us; for example, a radio, in part changes electrical energy to sound energy.

To give the pupils experience in generalizing the important concept of energy transformation, invite them to note and explain the source of the heat produced while a lead block is repeatedly pounded with a hammer. [Some of the energy of motion, in part, moves* lead molecules and part of the energy of motion is transformed to heat as lead molecules collide and resist movement.]

Summary Questions

1) Define these terms and give examples or demonstrate each one:

   (a) force
   (b) work
   (c) energy transformation

2) A boy pushes vigorously trying to make a car move, but it remains stationary. Does he do work on the whole car? Does he do any work? Explain.

3) Who would wear out the seat covers in a car first, a 250 pound woman or a 120 pound woman (assume same amount of time in the car and same kind of cover)?... explain in terms of work.

4) In which of the following situations is work performed? In which one is the most work performed? In which one is the least work performed?

   (a) A boy pushes his cart up a hill.

   (b) A truck rolls down a hill and crashes into a house.

   (c) A bird pulls a worm out of its hole.

   (d) A dog pulls at the end of his leash, but he doesn't move at all.

*The surface becomes dented.

EPISODE #6 (third of three pages)

5) In which of the following situations is work transformed (energy changed from one kind to another kind of energy)?

(a) A girl uses an electric hair dryer to dry her curls. Name the energy changes, if any. [Electrical energy is transformed to heat energy.] Where did the electrical energy come from? [Perhaps falling water, as at Niagara Falls... energy of motion.]

(b) The wind scatters fallen leaves all around. Name the energy changes, if any. [No appreciable change of energy in this example; the energy of motion of the wind is imparted to the leaves which also move.]

(c) A girl uses an electric sewing machine to stitch an apron together. Name the energy changes, if any. [Electrical energy is changed to energy of motion of the needle, etc.]

EPISODE #7

FACTUAL - CONCEPTUAL - INFERENTIAL (background)

This instructional episode is designed to give children background experience in applying the principle of energy transformation to entities whose actions are explained in terms of the electrical nature of matter.

At the completion of this instructional episode the pupil should be able to select correct statements about charged particles derived from certain electrostatic demonstrations.

Ask pupils to recall familiar phenomena with static electricity. This activity might well be preceded by using inflated balloons and noting their action on each other and on other objects after they have been rubbed against wool or plastics.

Then proceed to the following demonstration which introduces the basic principle of electrostatics; like electrical charges repel, unlike electrical charges attract.

1) Charge an "ebony" (actually made of hard rubber) rod by rubbing it vigorously several times in one direction with fur. It is known that such action, in effect, upsets the electrical neutrality of the substance of the rod; the action puts a negative (symbol is -) charge on the rod. Bring the ebony rod near the knob of a neutral electroscope...note the action of the electroscope leaves. They will diverge. Touch the ebony rod to the knob...note the action of the leaves. They will probably diverge farther. Remove the rod and touch the knob. The leaves will converge. This action grounds or discharges the charge on the scope, and it returns to electrical neutrality.

2) Repeat No. 1 with an uncharged ebony rod, a glass rod, a pencil, etc.

3) Charge a smooth glass rod by rubbing it very very vigorously several times in one direction with silk. It is known that such action, in effect, upsets the electrical neutrality of the rod; the action puts a positive (symbol is +) charge on the rod. Repeat the steps outlined in No. 1 with the glass rod.

4) (a) Touch a charged ebony rod to the knob of a neutral electroscope, then touch another charged ebony rod to the knob while keeping the first one in place.

(continued)

Describe the action of the leaves. The divergence will increase. What can be concluded about the action of negative charges on each other? [They repel each other.]

(b) Repeat A, but with two charged glass rods. Describe the action of the leaves. What can be concluded about the action of positive charges on each other? [They repel each other.]

(c) What can be concluded about the action of like charges on each other? They repel each other.

5) To the knob of a neutral electroscope, touch a charged glass rod, remove the rod, then touch a charged ebony rod. Ground the electroscope and repeat, reversing the order of the rods. Describe the action of the leaves:* [One type of charge gives a divergence, the other type added to it creates a convergence.] What can be concluded about the action of unlike charges on each other? [Unlike charges tend to attract each other.] One result of such attraction is to neutralize a previously charged body. For example, a positively charged body may be neutralized by negative charges which are attracted to it.

---

*Several suggestions for obtaining satisfactory results with the electrostatic apparatus follow :

1) When a charged rod is "touched" to the electroscope knob, run the rod along its length against the knob. This action maximizes the contact area between knob and rod.

2) Some people produce better electrostatic effects than others. Invite different children to participate.

3) Humid conditions may inhibit maximum results from electrostatic demonstrations.

(a) The glass rod usually gives the most trouble. Clean the surface by washing in a detergent or wiping with a paper towel saturated with alcohol. Dry thoroughly.

(b) Humidity in the classroom is usually lowest early in the day.

(c) An operating electric hot plate in proximity to the demonstration area may dry the air and apparatus. Plug-in well in advance.

EPISODE #7 (third of four pages)

As in earlier episodes, unseen entities are manifest here. The principle of repulsion of like charges and attraction of unlike charges is a fundamental one. It should be emphasized that the actions demonstrated are basic to explaining and predicting atomic and sub-atomic events. Encourage the pupils to hypothesize about what may be happening to the tiny bits that make up the ebony, the fur, the glass, the silk and the electroscope leaves. An acceptable hypothesis at this point would suggest that some things are added or are removed* from an electrically neutral object in the production of electrostatic phenomenon.

Summary Questions

1) Describe the energy transformation in this instructional episode. [Energy of motion is transformed to electrostatic energy.]

2) (a) What is meant by an electrostatically neutral object?

   (b) How does a neutral object become charged?

   (c) What is an electrical ground?

3) (a) How do negative charges affect each other?

   (b) How do positive charges affect each other?

   (c) How do positive and negative charges affect each other?

4) Which symbol is used to signify a:

   (a) positive charge? [+]

   (b) negative charge? [−]

   (c) neutralized charge? [o]

*The information that follows will be introduced to the pupils in subsequent episodes. It is known that negative electrical charges are derived from sub-atomic particles called electrons, and positive electrical charges are derived from sub-atomic particles called protons. In common applications, the loss of electrons from atoms makes it possible for the protons to "display" their charges. Taken alone an atom is thought to be electrically neutral, that is, the number of electrons equals the number of protons.

EPISODE #7 (fourth of four pages)

5) On a prepared worksheet (as below) each pupil should complete electroscope diagrams by drawing leaves in the correct position. The upper left diagram is completed as an example. It is suggested that the pupils' work be examined by the instructor to ascertain class progress.

I.

then→

II. ?

III.

?

then →

IV. ?

V.

?

then →

VI. ?

New Vocabulary

attract, repel
ebony rod
electroscope
electrostatic
electrical ground
negative
neutral, neutralized
positive
symbol

EPISODE #8

FACTUAL - CONCEPTUAL - INFERENTIAL (background)

This instructional episode is designed to give children background experience in using basic principles of work and the electrical nature of matter tc explain a transformation of energy.

At the completion of this instructional episode the pupil should be able to select correct statements about positive electrical charges (protons) and negative electrical charges (electrons) in relation to (1) their influence on like charges, (2) their influence on unlike charges, and (3) their relative mobility.

Invite the pupils to differentiate between the meaning of the words conductor and insulator, and ask for examples, expecially those in common electrical applications. Tell the pupils that nearly any material, even well known good insulators* can be made to conduct electricity if enough work is done on them.

The demonstration employs an electrophorus; it can achieve a larger charge than that of other inexpensive electrostatic devices. An electrophorus consists of a layer of plastic on a stand and a separate metal charge-carrying disc, which has an insulated handle. Each step is explained (see diagram and information below) from the standpoint of mobility of electrons. When a substance is electrically neutral the quantity of the protons and electrons are in balance. It requires work to unbalance the quantity of charges. Scientists tell us that in common applications, it is the relative mobility of electrons which accounts for the production of electrical effects when appropriate work is done. In general, if the work adds electrons, then negative charges abound, and if the work removes electrons then the effect of positive charges is manifest.**

(continued)

*Wood, normally a good insulator, can conduct, as when a tree or barn is destroyed by lightning. This common danger should be cited to the pupils.

**Some pupils may ask how to identify the polarity (+, -) of an unknown electrical charge. Place a known charge on an electroscope, then place the unknown charge on the scope. The polarity of the unknown charge will be indicated by the convergence (attraction) or divergence (repulsion) of the electroscope leaves.

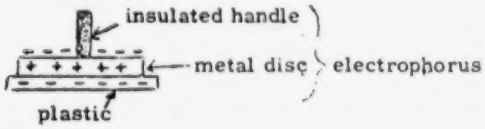
EPISODE #8 (second of three pages)

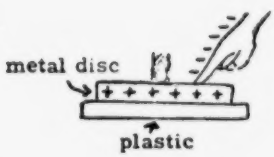
STEP 1

Rub the plastic plate vigorously with wool to charge the plastic negatively; this results in an excess of electrons on the plastic.

STEP 2

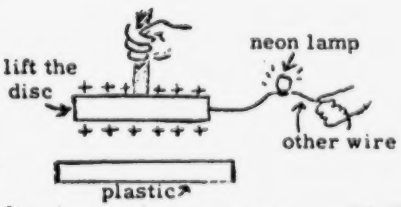
Place the metal disc on the plastic. The electrons of the disc are forced to the disc's top surface (why?) by the action of the excess electrons on the plastic below.





STEP 3

Touch the disc...this action removes the electrons from the top surface of the disc because "ground" is more attractive than the repulsion effect from the negative charges on the plastic plate. The metal disc is now positively charged.



STEP 4

Lift the disc from contact with the plastic plate. Touch the disc to a bared end of a wire lead from a 1/25 watt neon* lamp. A brief red flash of the lamp indicates that an electric charge is flowing across it (from where?) to neutralize the positively charged disc. The "other" wire from the bulb may not require a connection to complete the circuit because the electrons in it may suffice as a source of charges. If the bulb does not flash, clip the "other" wire to a metal object, or even hold the bared end firmly between your thumb and forefinger.

*The neon bulb is a miniature version of the ones used in electrical advertising signs often seen at restaurants and shopping centers, etc. Given an appropriate electrical circuit, neon gas in a bulb will glow a red color.

Show pupils that the light will not flash if no work is done in STEP 1. The emphasis throughout is to give the pupils experience in accounting for the observations in terms of the relative mobility of electrons, as compared to protons.

Summary Questions

1) (a) Usually plastics are electrical insulators. What had to be done to the plastic in this demonstration for it to become electrified?

   (b) Give common examples in which insulating substances may become electrified, or conduct electricity.

2) What specific work was done to produce electricity in the demonstration?

3) Where did the electrons come from to light the bulb?

4) Why did the bulb flash, then go out? [Electrons did work (light energy) "on the way" to neutrality in the disc.]

5) In which steps in this demonstration is it inferred that:

   (a) like electrical charges repel each other? [Step no. 2]

   (b) neutrality was re-established: [When the light flashes and goes out... end of step no. 4.]

6) Scientists tell us that charged particles, and hence, electricity comes from the atoms from which all things are derived or made. Further, scientists tell us that it is negative charges or electrons that are involved in carrying electricity or in "movement" of electricity. In view of this information what part of the atom, "inside" or "outside," would most likely consist of protons? Explain.

New Vocabulary

electron, proton
electrophorus
conductor
insulator
neon

EPISODE #9

FACTUAL - CONCEPTUAL

This instructional episode is designed to impart to children the idea that the universe is composed of a limited number of elements which make up all classes of substances. From earlier episodes the principle of energy transformation is brought to bear on the basic relationships between atoms and molecules.

At the completion of this instructional episode, the pupil should be able to select correct statements which relate to:

1) the definition of chemical element, mixture and compound and the relation between them (rigor of definitions will be sacrificed for ease of comprehension).

2) the definition of atom and molecule and the relation between them (rigor of definitions will be sacrificed for ease of comprehension).

3) the most general qualitative attributes which differentiate the approximately 100 chemical elements at the atomic level.

Referring to some of the materials used in earlier demonstrations such as ebony (hard rubber), glass, wool, silk, wax, leaves of an electroscope, tell the pupil that all things in the world, including plants and animals, sun and stars, are thought to be comprised of one or more of about 100 different elements, in various combinations. Name several well-known elements (iron, silver, aluminum, carbon, hydrogen, oxygen, nitrogen, zinc, radium, uranium, etc.) and relate to pupils' lives and experiences. At this point relate the word atom to the concept of element. Do not push for a deep understanding... it will be treated more rigorously in a later instructional episode. Ask the pupils to give a general hypothesis to explain the existence of so many <u>other</u> substances (give examples such as water, sugar, salt, protein*, wax, silk, ebony, wool, etc.) besides the elementary 100. An analogy may help: in a wardrobe of clothes of different styles, colors, etc., there is a large number of possible combinations that could be worn. However, some possibilities are "more satisfactory" than others. Give examples and let pupils give examples; brown and black shoes

(continued)

*Proteins are a class of complex compounds which give evidence of being involved with the basic chemistry of life in all living things. Proteins are in general composed of the elements nitrogen, hydrogen, oxygen, carbon and often sulfur.

(split pair) etc., vs. 2 browns, 2 blacks, or swimming trunks and T-shirts vs. swimming trunks and overcoat. The important generalization here is that elements may combine, but there are easier or "more satisfactory" combinations with some elements compared to others.

There are two general modes by which substances, including elements, may enter into combination; these modes are mixtures* and compounds. Demonstrations follow which should involve the pupils in differentiating, via discussion, between mixtures and compounds. Use approximately equal and <u>small</u> quantities of powdered zinc (an element) and powdered sulfur (an element). Use a clean end of a wood splint to spoon out once from each container, and mix the powders a bit in a small porcelain crucible. Close the chemical containers before proceeding. Give the pupils a definition for mixture which emphasizes the operational possibility of separating the substances again, "by hand"; demonstrate separation by picking out a few grains of one of the powders.**

Now proceed to make a compound from the mixture of zinc and sulfur. Make a compact mound of the mixture in the crucible, so that it will hold the heat from a burner. With long tongs, hold the crucible over a flaming burner. Be sure the pupils are well away from the reaction because it will produce intense heat and light. Once the mixture starts to glow, remove the crucible from the flame, set the crucible down and stand back...there will be forthcoming a great release of energy. Compare the color of the new compound zinc sulfide (white) with the colors of the original reactants. Zinc is grey, sulfur is yellow. Remind the pupils that the reactants are elements, and re-emphasize the definition of an element. Emphasize that work, in this case, heat energy, was needed to start the reaction and there is a release of energy as a consequence of the reaction that forms the new substance, a compound. Underscore the idea that the compound zinc sulfide did not exist as such before the reaction and that it <u>always</u> forms under the same conditions.

---

*There are other modes of combinations associated with mixtures, i.e., mixtures of compounds, and mixtures of compounds and elements. An example of the latter is air; examples of the former are products such as Coca-Cola and Bufferin.

**The proportion of reactants that make up a compound are invariable. However, a mixture can vary in the proportion of its substances. For example, the wheat cereals we buy (Wheaties, Pep, etc.) are made from the same basic compounds, but they are mixed in different proportions to attain a difference in taste.

Put another way, when substances (elements and/or compounds) are put under conditions in which a new compound can be formed, the new compound will always be formed.*

The term molecule can now be introduced in a somewhat more rigorous (but not complete) sense than used in earlier activities; a molecule is the smallest sub-division of a compound that has the compound's properties.** An approximate contrast may be helpful: atoms are to elements as molecules are to compounds.

Some pupils may now ask if compounds can be broken down into their constituent substances. At this point the lesson could be terminated until the next session.

A demonstration of breaking a compound into the elements follows. Place enough of a compound mercuric oxide in a heat-resistant test tube (small) to fill the tube to the level shown in the diagram. Do not let the mercuric oxide cling to the inside wall of the test tube... lightly cork the test tube and heat, moving it back and forth over a flaming burner. When the contents become thoroughly blackened, remove the cork and quickly insert a glowing (not flaming) splint. It should burst into flame;*** this indicates the issuance of the element oxygen. Note the silvery droplets of the element mercury which deposit on the inside of the tube.**** Outline the results on the chalkboard using the following word equation:

*The compound zinc sulfide could be broken into its constituent elements, but it would require much work or energy to do so. Some other compounds are more easily broken into component elements as will soon be described.

**The term molecule may also apply to polyatomic forms of certain elements, mostly elemental reactant gases under normal conditions.

***If the first attempt fails, cork the tube, reheat and try the test again.

****Referring to earlier episodes, it might be noted that energy is used to change a solid into a liquid and a gas. However, the change here is chemical not physical...Why? [A physical change is limited to a change in shape or a change in state, such as gas to liquid. Chemical changes very often include physical changes but, in addition, there is formed one or more substances with wholly new reactive (chemical) properties.]

EPISODE #9 (fourth of six pages)

(compound) mercuric oxide (molecule) —Add heat energy→ (element) mercury (atom) + (element) oxygen (atom)

Emphasize that in this case a compound composed of two elements has been broken down to release its elements.* Compare the word equation for the decomposition of mercuric oxide with the earlier reaction in which a compound is formed:

(element) zinc (atom) + (element) sulfur (atom) —add heat energy→ (compound) zinc sulfide (molecule)

Ask certain pupils to come to the chalkboard to indicate on each word equation where the terms atom and molecule should be properly placed. The emphasis here should be upon the three objectives stated at the top of page 1, not in memorizing word equations.

Invite the pupils to generalize, via discussion, the conditions for making a compound or breaking a compound into its elements. [In both cases energy, or work is required.]

Summary Questions

1) What are the definitions for each of the following terms?

Where relevant, give a common example.

element	compound	energy
mixture	atom	molecule

2) As we have defined them, which would have the most elements represented in it, an atom or a molecule?

3) (a) A scientist breaks a compound into its elements. Which one of the 4 statements below outlines what is thought to happen at the level of the atoms and molecules. Explain. [#2]

1) compound to mixture
2) molecule to atom
3) atom to molecule
4) proton to molecule

*It might be mentioned that many compounds contain more than two elements. One of the most common is sugar which contains the elements carbon, hydrogen, and oxygen.

3) (b) A scientist creates a compound from certain elements. Which one of the 4 statements above outlines what is thought to happen at the level of the atoms and molecules? Explain. [#3]

4) Scientists tell us that there are approximately 100 different elements which make up all the things in the universe. Which one of the three statements below best states the relation of the elements to the make-up of all substances? [C]

A) all substances are mixtures

B) all substances are either elements, or a mixture of elements

C) all substances are either an element, or are compounds, or are a mixture of elements and/or compounds.

5) When the element oxygen and the element hydrogen are mixed, nothing happens until a spark or flame is introduced into the mixture. Then an explosion occurs and the compound water, in some quantity, is <u>always</u> formed. Relate the substances described above to the terms atom and molecule by filling in the chart below.

	oxygen	water	hydrogen
element or compound?			
atom or molecule?*			

*Oxygen and hydrogen each readily exist in diatomic (two closely associated atoms of the element) form and as such are commonly called "molecules." In these instructional episodes the term molecule will be used only in reference to compounds.

EPISODE #9 (sixth of six pages)

New Vocabulary

atom	molecule
composition	oxygen
compound	reaction
element	splint
energy	substance
mercury	sulfur
mixture	zinc

EPISODE #10

FACTUAL - CONCEPTUAL - INFERENTIAL

This instructional episode is designed to give children an experience in recapitulation of certain profound ideas concerning the development of a reasonably valid model of the atomic nature of matter. This episode draws on earlier experiences in electrostatics and making inferences about unseen entities.

At the completion of this instructional episode the pupil should be able to select correct statements concerning the experiment and inferences which led from the Kelvin-Thompson "jelly-roll" model of the atom to the Rutherford-Bohr planetary model of the atom.

Ask the pupils to try to imagine the tiniest entities of which the material of the world is made. Some scientists, not too long ago, imagined these entities or atoms as sort of a spherical ball (see drawings) of jelly-like positive charges in which there would be embedded one or more negative charges, depending on the element. Scientists knew that atoms had negative charges (electrons) and positive charges (protons), but their arrangement was a mystery. They correctly surmised that electrons were responsible for certain manifestations of energy, among them, heat and light. In reference to the jelly-roll idea, if electrons were pulled about within the "jelly" by having work done on them, they would give up energy in the form of heat and light.

Diagram I is an approximate representation of a "jelly-roll" atom which has several randomly arranged electrons and protons. If the "jelly-roll" model is a good one, then high speed, positive* charges, fired at a mass of such atoms from the outside, would be expected to take what path(s)? Invite the pupils to predict what path the proton projectiles would take, and defend their predictions. Then draw Diagram II on the chalkboard. Diagram II represents what was thought would happen if the target atoms were analogous to the"jelly-roll"idea.

If the atom is analogous to the "jelly-roll" conception then the path of proton projectiles should be slightly bent as the projectiles come under the repulsion influence of the randomly-arranged target protons (Diagram II). Electrons of

(continued)

*Protons have much more mass ("weight") than electrons. Therefore, it was expected that protons fired at high speed would not be easily deflected by randomly arranged positive charges of the target nor be captured or slowed by negative charges of the target.

EPISODE #10 (second of three pages)

the target might only speed-up oncoming protons by attraction and slow them a bit as the protons pass by. When the pupils seem to understand this logic, then show them what really occurred, as in Diagram III.

Dramatize that Diagram III represents what happened when Rutherford experimentally tested the "jelly-roll" model of the atom. From the diagram it will be seen that some protons got through unmolested...in fact, most of them did, but a few that didn't were either very sharply deflected, or actually came directly back! The pupils should be led to infer that:

1) atoms seem to be mostly empty space;

2) there is a central portion that has a large, positive charge;

3) the planetary atomic model seems to be a better representation than the "jelly-roll" model.

Diagram I

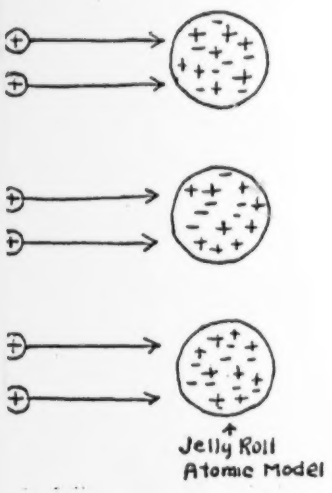


Diagram II

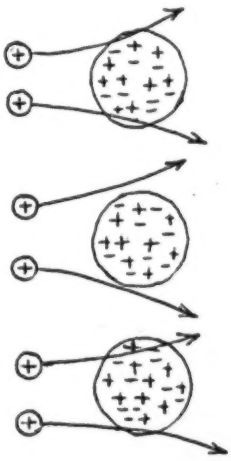
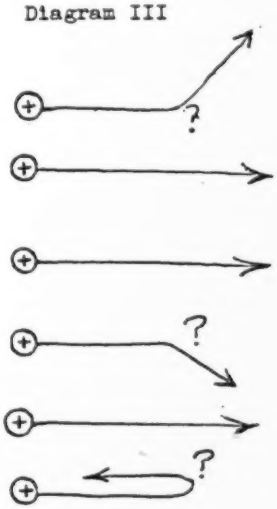


Diagram III



* ⊕——→ represents many, many protons driven at high speeds.

EPISODE #10 (third of three pages)

When pupils apparently accept the foregoing, the following questions can serve to extend and reinforce pupils' conceptions about the planetary atomic model.

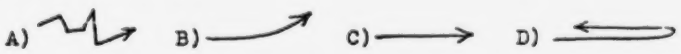
1) For a source of target atoms, Rutherford selected elements having the property of being dense. What was the basis for his reasoning? [High speed protons would more likely be influenced because of more targets.]

2) Assuming there are electrons associated with each atom, what can be inferred about their distance from the nucleus of the atom? [Electrons must be far away and in motion, otherwise the cluster of positive charges in most nuclei would attract them so much that electrons would fall into nuclei.]

3) The planetary atomic model seemed to "solve" some important problems for scientists, but it made problems, too. Can you spot one of them? Hint: consider nuclei which have more than one proton and then recall the rules for electrostatic attraction and repulsion!

Summary Questions

1) If high speed positive particles were fired at atomic targets, which one of these drawings shows the expected path if protons were mixed evenly with electrons throughout target atoms? Explain. ["B". See explanation on p. 2.]



2) Repeat No. 1 except the high speed positive particles are fired at an atomic target with closely packed protons; which arrow(s) represent(s) what occurred in Rutherford's experiments? ["C" mostly, and "D" occasionally.]

3) Scientists claim that atoms are mostly empty space. How did Rutherford's experiment help to infer such a conclusion? [Most of the projectiles went through seemingly solid targets, without being deflected.]

New Vocabulary

atomic target
embedded
deflect

EPISODE #11

FACTUAL - CONCEPTUAL - INFERENTIAL

This instructional episode is designed to impart to children basic understandings about the sub-atomic attributes of selected elements. It draws upon earlier experiences which dealt with the electrical nature of matter.

At the completion of this instructional episode, the pupil should be able to use a chart of atomic properties (p. 5) to select correct statements which relate to a basic body of content on the general structure of the planetary atomic model.

The introductory statements herein should be presented via lecture: In order to account for differences in the elements in such features as color, density, relative conductivity of heat and electricity, relative ability to form gases, liquids, solids, and ability to form new substances, it is evident that there must be differences in the structure (make-up) of the smallest division of an element which has all the properties of that element...an atom of that element.

Based on experiences in earlier activities ask the pupils to consider a difference they noted between zinc and sulfur, both of which are elements; [Color]. Tell them that the last bit of zinc that has all of zinc's properties will be different from the last bit of sulfur that has all of sulfur's properties. These last bits are called atoms. Ask the pupils to make mental comparisons of properties among such familiar elements as iron, oxygen, copper, sulfur, aluminum, etc; (Compare properties of color and common physical state.)

Now, invite the pupils to make general hypotheses about the features of the "smaller-yet", or sub-particles of atoms which could have a bearing on the differences each element's atoms display compared to all other elements' atoms. What is sought here are responses of the following types: "built different", "have different parts", "some have more parts than others", etc. If progress here is too slow, ask why water vs. alcohol (neither are elements, both in their pure form are compounds) have such different properties (demonstrate burning, odor) though they look alike.

At this point, explain that scientists have evidence that the differences between atoms of elements are due to differences in the number and arrangement of three basic types of sub-atomic particles (smaller yet than whole atoms). The three basic particles of atoms are:

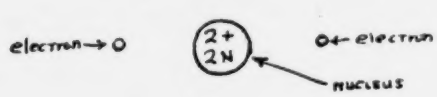
(continued)

1) Electron - a negatively charged particle which orbits outside the nucleus or central portion of the atom... there are several likely orbiting paths called shells.

2) Proton - a positively charged (opposite of electron) particle which is found as part of the centrally located nucleus. It has nearly 2,000 times more mass ("weight") than an electron.

3) Neutron - an electrostatically neutral particle which is found in the nuclei of all atoms except the most common type of hydrogen. It can be considered as equal in mass ("weight") to the proton. A neutron is thought to be composed of a positive charge and a negative charge.

On the chalkboard or overhead projector, draw a diagram of a simple atom, such as helium, $^{4}_{2}He$.



Nucleus contains:

2 protons
2 neutrons
4 = atomic mass ("weight")

Tell the pupils that this is a simplified picture of what is now known; in fact, there is strong evidence that it is not this simple, but is a good start in learning how the world is structured from tiny entities. Ask the pupils which part of an atom, electrons or protons, would they expect to be most easily removed. Remind them of their experiences with electrostatics.

Provide each pupil with the chart of the first 20 elements (similar to the one on page no. 5) for their continual reference. Invite them to make drawings of some of the lighter elements in their notebooks. Point out that all elements, except hydrogen*, have neutrons in their nuclei. Emphasize

*Hydrogen, too, is known to have some atoms with neutrons in the nucleus. Atoms, with more or fewer neutrons than "normal" are called isotopes; many such examples exist with other elements. The compound known as heavy water, contains an isotope of hydrogen. The concept of isotopes is not pursued in these instructional episodes.

that the electrons are arranged about the nucleus in successive shells, according to certain rules (to follow). At first ask them to copy the teacher's chalkboard (or overhead projector) drawings. The teacher should give individual help to assure that pupils are drawing their atomic representations in an orderly fashion.

As some mechanical skill in drawing becomes evident, the pupils should be told the following:

1) The drawings, as we make them, are very much over-simplified. But, it <u>is</u> a good way to begin to learn interesting ideas about the composition of the universe.

2) The electron(s) should be thought of as orbiting in a cloud-like shell* at various relatively "fixed" distances from the nucleus.

3) Most of the atom is empty space. Give the following analogy about an atom of hydrogen: If the nucleus were the size of a golf ball, the electron would be buzzing around it about 2 miles away.

It may prove advisable to terminate the activity here and continue at the next session.

After the pupils have had experience in drawing representations of several light elements, they should be led to "discovering" the following rules for determining the atomic structure, via questions from the instructor, and continual reference to their charts.

1) The atomic number always equals the number of positive charges (protons) in the nucleus.

2) The atomic number equals the number of negative charges (electrons) that circulate around the nucleus of a neutral atom.

3) The atomic mass ("weight") minus the atomic number equals the number of neutrons. For the element chlorine: atomic mass = 35, atomic no. = 17, therefore, the number of neutrons = 18 in a "normal" atom of chlorine.... give other examples for drill.

*For the sake of simplicity, we will draw shells as concentric circles.

4) The number of electrons in the first shell outside the nucleus cannot exceed two.

5) The number of electrons in each of the second and third shells does not exceed eight up through element no. 20.

At this point the pupils should be invited to hypothesize about the properties of certain elements, based on our simplified look at atomic structure. For example, ask the pupils to note that in a set of four metallic elements made into cylinders of equal weight, each has a different volume. Invite the pupils to account for the differences discussing it in terms of general atomic structure.* Despite earlier experiences in these instructional episodes, it can be expected that some of the pupils will not have a definitive conception of volume, much less density. However, a conception of weight can be expected, and from this the notion of a difference in density should be re-introduced.

* Aluminum, atomic no. = 13; atomic mass ("weight") = 27
Zinc, atomic no. = 30; atomic mass ("weight") = 65
Tin, atomic no. = 50; atomic mass ("weight") = 119
Lead, atomic no. = 82; atomic mass ("weight") = 207

THE FIRST 20 ELEMENTS: CHART OF BASIC ATOMIC PROPERTIES

Atomic Number	Element	Symbol	Basic * Chemical Property	Atomic Mass ("weight")	Protons	Neutrons	Electron Arrangement in the shells 1st	2nd	3rd	4th shell
1	Hydrogen	H	M	1	1	0	1			
2	Helium	He	inert	4	2	2	2			
3	Lithium	Li	M	7	3	4	2	1		
4	Beryllium	Be	M	9	4	5	2	2		
5	Boron	B	M	11	5	6	2	3		
6	Carbon	C	Ind.	12	6	6	2	4		
7	Nitrogen	N	Nm	14	7	7	2	5		
8	Oxygen	O	Nm	16	8	8	2	6		
9	Fluorine	F	Nm	19	9	10	2	7		
10	Neon	Ne	inert	20	10	10	2	8		
11	Sodium	Na	M	23	11	12	2	8	1	
12	Magnesium	Mg	M	24	12	12	2	8	2	
13	Aluminum	Al	M	27	13	14	2	8	3	
14	Silicon	Si	Ind.	28	14	14	2	8	4	
15	Phosphorus	P	Nm	31	15	16	2	8	5	
16	Sulfur	S	Nm	32	16	16	2	8	6	
17	Chlorine	Cl	Nm	35	17	18	2	8	7	
18	Argon	Ar	inert	40	18	22	2	8	8	
19	Potassium	K	M	39	19	20	2	8	8	1
20	Calcium	Ca	M	40	20	20	2	8	8	2

Drawing of
silicon (Si) atom
atomic no. =14
no. of neutrons=14
atomic mass ("weight")=28

Electron arrangement of silicon
1st shell = 2 electrons
2nd shell = 8 electrons
3rd shell = 4 electrons

M = mostly acts like metal
Nm = mostly acts like non-metal, however there are important exceptions with nitrogen, sulfur and phosphorus.**
Ind. = indeterminate; can act like a metal or non-metal

*The pupils' charts do not contain the column entitled, "Basic Chemical Property," nor the information entered below row no. 20.

**It might be well to mention to the pupils that there are common exceptions to most of the "rules", or patterns stated herein. There are valid explanations for many of the exceptions, but they are embodied in the content of advanced studies.

EPISODE #11 (sixth of seven pages)

Summary Questions

1) In atomic structure where do the negative charges exist?, positive charges?

2) If the atomic number is known, the quantity of what two basic parts of a neutral atom are known? [Protons and electrons.]

3) (a) What two parts of atomic structure make up atomic mass ("weight")? [Protons and neutrons.]

   (b) Describe the electrostatic charge of each of the two parts named in "a". [Protons carry a positive charge. Neutrons carry a positive and negative charge, hence, neutrons are electrostatically neutral.]

4) What are the relative masses ("weights") of these atomic particles?.... Use the terms most, least, same.

   (a) electron (b) proton (c) neutron

5) If the atomic number and the atomic mass ("weight") are known, how can the neutron, complement of an atom, be computed? [From the atomic mass subtract the atomic number. Give pupils several examples to work out such as helium, beryllium, oxygen, magnesium, phosphorus, argon.]

6) Given equal volumes, which element would you expect to be heavier, aluminum or magnesium? Why? Use the chart. [Aluminum has more particles in the nucleus.]

7) At ordinary temperatures the following elements are gases: hydrogen, helium, oxygen, nitrogen. Air is a mixture of mostly oxygen and nitrogen. Why are hydrogen and helium used in balloons and dirigibles? Use the chart. [If 4 balloons are each filled with equal volumes of these gases, then the hydrogen and helium balloons would float in air. Hydrogen and helium atoms have less mass ("weight") than do nitrogen and oxygen atoms which compose the air.]

8) Name the element(s) in the chart of the first 20 elements which:

   (a) have the most electrons in their outermost shell, [Neon, argon...each has 8 electrons.]

(b) have the same number of neutrons, [Boron, carbon = 6; fluorine, neon = 10; sodium, magnesium = 12; aluminum, silicon = 14; phosphorus, sulfur = 16; potassium, calcium = 20.]

(c) have the same atomic mass ("weight"). [Argon and calcium, both = 40.]

9) (a) Which element in the first 20 elements has the most neutrons? [Argon = 22.]

(b) Does it have the greatest atomic mass ("weight")? [No, but argon's atomic mass ("weight") is the same as calcium with an atomic mass ("weight") of 40.]

New Vocabulary

arrangement
atomic mass ("weight")
atomic number
electron shell(s)
nucleus
orbit
outermost
particle(s)
represents
symbol

EPISODE #12

FACTUAL - CONCEPTUAL

This instructional episode is designed to give children experience in using the planetary atomic model to classify certain elements as metallic, non-metallic, indeterminants, or inert; these chemical characteristics are employed in accounting for the formation of selected compounds.

At the completion of this instructional episode the pupil should be able to select correct statements which explain (in terms of the planetary atomic model) the tendency of certain elements to (1) act like metals, (2) act like non-metals, (3) be indeterminant as to metal and non-metal, (4) be "inert".

With forceps hold a piece of magnesium ribbon in the flame of a burner until it begins to burn. Avoid looking directly at the flame. Emphasize that the burning is release of energy (heat and light). Invite the pupils to observe the product. Tell the pupils that the element magnesium has combined with the element oxygen from the air. Ask the pupils to use their atomic charts from an earlier instructional episode to help hypothesize a possible explanation for the ready combination of magnesium atoms and oxygen atoms. See diagram on page 2. Invite them to draw a diagram of each atom. The explanation is expected to be difficult to elucidate. The pupils should then be told that some types of atoms tend to effect a complete outer shell by gaining electrons which they "acquire" from other types of atoms. The completion of the outer shell for the first 20 elements follows these rules:

1) A maximum of two electrons can appear in the shell next to the nucleus.

2) A maximum of eight electrons can appear in each of the two more distant shells.

Ask pupils to verify these rules in their atomic charts. Employ a short recitation of examples to help reinforce the verification.

Now, begin a lecture-discussion which uses these rules to eventually elicit hypotheses from the pupils relevant to other possible combinations of some elements. Explain that many elements have a tendency to complete outer shells of their atoms, as in the rules above. Use the analogy that the rich get richer, and the poor get poorer to introduce the concept that atoms with fewer than four electrons in their outermost shell tend to share or even lose their outer electrons to yield a complete shell (next shell in toward nucleus)

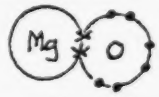
(continued)

and those that have more than four electrons (except those that have eight electrons in the outer shell) tend to take on electrons to complete a shell. Emphasize the tendency to complete outer shells by sharing (or giving up), or by gaining electrons. Atoms with exactly four outer electrons, such as carbon, may go either way and are herein called indeterminant. Atoms that tend to share or lose electrons and thus expose a complete (or more complete) shell nearer to the nucleus are called metals. Atoms that tend to gain electrons to complete a shell are called non-metals. Give examples of common metals such as magnesium, iron and aluminum in the first 20 elements. The gas hydrogen may act like a metal because of its tendency to share its lone electron. Invite the pupils to give other examples of metals. Next, give examples of non-metals in the first 20 elements...ask the pupils to do likewise using the rules outlined above. Certain elements have filled outer shells and are called the inert elements.* They are not likely to enter into chemical combinations. The inert elements, where found, are uncombined or free.

A worksheet (see p.) is employed to give the pupils experience in using the atomic chart from an earlier instructional episode to confirm the chemical characteristics of the first 20 elements as being metallic, non-metallic, indeterminant, or inert. For each element the pupil selects one of the four characteristics and also a rationale or explanation, labeled A, or B, or C, or D. Several examples are given.

Plan to take sufficient time with the Worksheet on the Basic Chemical Properties to insure that most of the pupils can demonstrate a facility with the rules. Then ask the pupils to recall the demonstration with magnesium and oxygen...invite the pupils to give an explanation for the combination of these two elements and the release of energy. An acceptable explanation would suggest that magnesium's two outer electrons are shared by oxygen, forming the compound magnesium oxide. Furthermore, enormous numbers of atoms are combining by the sharing of electrons to form the new substance. The energy given up in the form of heat and light was, in effect, the energy that

Diagram of molecule of magnesium oxide



Magnesium's outer electrons = ××

Oxygen's outer electrons = ••

*In the first 20 elements, the following elements have filled outer shells: helium, neon, argon.

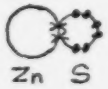
kept the metal magnesium and the gas oxygen in their respective uncombined forms. When they combined (it took some heat energy to start it), they gave up their "excess" energy. It may require two or more sessions to reach this point in the presentation.

As a consequence of the experiences outlined above, invite the pupils to discuss and diagram the hypothetical electron exchanges, if any, between some other elements; a selection follows on page 4. The pupils should attempt to make their own diagrams (as shown) of the electron complement of the outer shells in the appropriate cases, and certain pupils could be asked to put their representations on the chalkboard. The discussion should be supplemented where necessary by the teacher's chalkboard diagrams.

WORKSHEET ON THE BASIC CHEMICAL PROPERTIES OF THE FIRST 20 ELEMENTS

A = outer electron shell is filled (8 electrons except for helium which is filled by 2 electrons)
B = outer electron shell has 1, or 2, or 3 electrons (less than 4)
C = outer electron shell has 5, or 6, or 7 electrons (more than 4, but less than 8)
D = outer electron shell has 4 electrons

Atomic No.	Element	Acts like Metal	Acts like Non-Metal	Can act like Metal or Non-Metal (Indeterminant)	"Inert"	Letter of Reason
1	Hydrogen					
2	Helium				X	A
3	Lithium					
4	Beryllium					
5	Boron					
6	Carbon			X		D
7	Nitrogen					
8	Oxygen		X			C
9	Fluorine					
10	Neon				X	A
11	Sodium					
12	Magnesium					
13	Aluminum					
14	Silicon					
15	Phosphorus					
16	Sulfur					
17	Chlorine					
18	Argon					
19	Potassium	X				B
20	Calcium					

Hydrogen and chlorine	Hydrogen's electron can, in effect fill chlorine's outer shell which contains 7 electrons, thus completing hydrogen's (up to 2 electrons) and chlorine's (up to 8) outer shells. Diagram of hydrogen chloride molecule showing hydrogen's outer electron (x) and chlorine's outer electrons (••) 	Compound formed is hydrogen chloride (HCl), a gas used to make a very useful acid.
Sodium and chlorine	Analogous to above 	Compound formed is NaCl, common salt, found expansively in nature.
Neon and helium	No reaction, ordinarily; both shells filled	
Argon and oxygen	Argon has a filled (8 electrons) outer shell and will not react, ordinarily.	
Zinc (not in first 20 elements) and sulfur	Zinc has 2 outer electrons, hence, they can be shared with sulfur's 6 outer electrons; this, in effect, completes the outer shell for both elements. Diagram of zinc sulfide molecule showing zinc's outer electrons (xx) and sulfur's outer electrons (••)  	Compound formed is ZnS, zinc sulfide (the reaction was demonstrated.)

In each of these cases, after the pupils have worked out the possibility, tell them the name and importance of the compound formed (if any). Terminate the activity at any time that confusion overtakes apparent progress. Continue at the next session with a review; use short lecture and examples on chalkboard, and ask pupils to discuss their reasoning. Invite questions.

Summary Questions

Questions which summarize the expectations stated in the lead paragraph are implied in the worksheet activities.

New Vocabulary

maximum - minimum
indeterminant
inert
product
tends, tendency

EPISODE #13

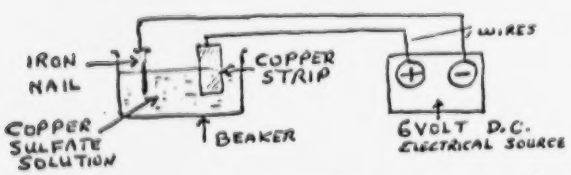
FACTUAL-CONCEPTUAL

This instructional episode is designed to give children experience in accounting for the phenomenon of atomic polarity (charged atoms). Principles of electrostatics and chemical characterists of classes of elements are drawn from earlier episodes.

At the completion of this instructional episode the pupil should be able to select correct statements about the nature of charged atoms following a demonstration of electrolysis.

Fill a small beaker 2/3 with warm water. Stir in about 1/2 teaspoonful of copper sulfate crystals ($CuSO_4$) until most of the crystals dissolve. The solution will have a bright blue color. Connect a clean* copper strip and a clean iron nail to a 6 volt D.C. electrical source as shown in Diagram I. Immerse only the copper strip and the nail in the solution, not any of the terminal or supporting apparatus. The copper strip and nail should not touch each other.

Diagram I



+ = positive pole

- = negative pole

Soon a deposit of copper "threads" will appear on the iron nail and at the same time the copper strip attains a rather etched surface.

The pupils should be invited to discuss the following problem: How can copper atoms, which are said to be electrically neutral (see Diagram II), be pulled from a copper strip, migrate, and be deposited elsewhere?**

(continued)

*Use scouring powder, or steel wool, or fine sandpaper.

**Only the migration of copper is considered herein. In any electrolysis there is some type of reciprocal action.

Diagram II

Neutral Atom of Copper*

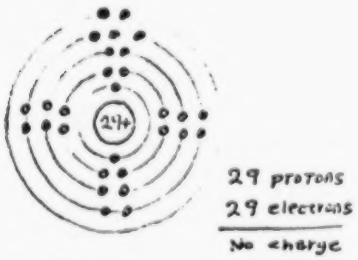
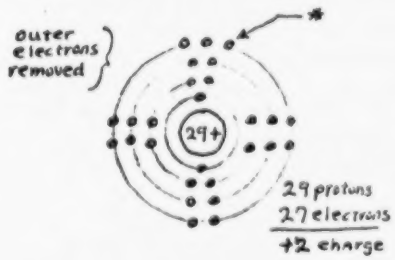


Diagram III

Charged Atom of Copper



[The electrical source does work to remove the two outer electrons from the neutral copper atom. This leaves 27 electrons, and, of course, the 29 protons...hence, the atom now displays two positive (+2) charges and is called a charged copper atom; see Diagram III. Positively charged copper atoms are attracted to the iron nail which is the negative pole of the electrolysis circuit. At the negative pole each charged copper atom, in effect, re-acquires two electrons and is neutralized; it is the neutral atoms which cling loosely to the iron nail.]

The following questions and activities should be woven into the discussion from which the main inference is to be derived.

1) What is the function of the electrical source? [It provides energy, or does work, to move electrons.]

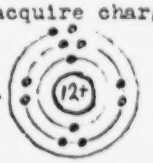
2) What must be done to an atom of an element for it to become charged? [Electrons must be added or taken away.]

3) Explain why the copper is removed at the positive pole in electrolysis and deposited at the negative pole. [See first paragraph, this page.]

*The element copper does not follow the rule for completion of electron shells as given in an earlier instructional episode. This exception is not part of the lesson at hand. Copper was selected for the demonstration because it so readily shows the overall effects stated in the objective for this instructional episode.

EPISODE #13 (third of six pages)

4) Atoms of other elements can acquire charges. Draw diagrams of the following:

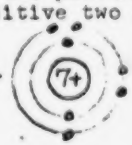
(a) an atom of magnesium → 

12 protons
12 electrons

(b) a charged atom of magnesium; explain the difference between a and b. →

12 protons
? electrons
2 positive charges [10]

[Magnesium, a metal, has two outer electrons which it can readily give up. The loss of these two electrons unbalances the electrical neutrality of the atom, and "exposes" two protons. Thus, a charged magnesium atom has a positive two charge.]

(c) an atom of nitrogen → 

7 protons
7 electrons

(d) a charged atom of nitrogen; explain the difference between c and d. →

7 protons
? electrons
3 negative charges [10]

[Nitrogen, in this case, is to be considered a non-metal (there are important exceptions for nitrogen). It tends to acquire three electrons to complete its outer shell. The gain of the three electrons unbalances the neutrality of the atom by a factor of three negatives. Thus, a charged nitrogen atom has a negative three charge.]

Summary Questions

1) See questions No. 1 - 4, above.

2) In an earlier instructional episode, we learned that some elements are metals, some are non-metals, some may act both as a metal or a non-metal, and some are inert. In regard to the metals and non-metals of the first 20 elements, which ones tend to:

   (a) lose electrons to become charged atoms? [H, Li, Be, B, Na, Mg, Al, K, Ca.]

   (b) gain electrons to become charged atoms? [N, O, P, S, Cl.]

3) If the compound water is electrolyzed, the elements oxygen and hydrogen are obtained.

   (a) Which drawing, A or B, represents a neutral atom of hydrogen; a charged atom of hydrogen? Explain. ["B" represents the neutral atom...the protonic charge is balanced by charge on electron.]

   (A)

   (B)

   (b) To which pole in electrolysis would a charged atom of hydrogen be attracted? Why? [The negative pole, because hydrogen's outer electron is removed in electrolysis, thus displaying its protonic (+) charge.]

   (c) Does it act like a metal or non-metal? Explain. [Metal; it tends to share or even give up its electron.]

   (d) Which drawing, C or D, shows a neutral atom of oxygen; [C] a charged atom of oxygen? [D]

C

D

EPISODE #13 (fifth of six pages)

(e) To which pole in electrolysis would a charged atom of oxygen be attracted? Why? [The positive pole, because oxygen acquires two electrons to fill its outer shell, and thus displays two "excess" negative charges in comparison to its 8 protonic charges.]

(f) Does it act like a metal or non-metal? Explain. [Non-metal; it tends to acquire electrons to fill its outer shell.]

4) (a) Draw a picture representing a charged atom of each of the metallic-acting elements of the first 20 elements.

[$_{1}H$ = no electron, shows positive one charge

$_{3}Li$ = two electrons, shows positive one charge

$_{4}Be$ = two electrons, shows positive two charge

$_{5}B$ = two electrons, shows positive three charge

$_{11}Na$ - ten electrons, shows positive one charge

$_{12}Mg$ = ten electrons, shows positive two charge

$_{13}Al$ = ten electrons, shows positive three charge

$_{19}K$ = eighteen electrons, shows positive one charge

$_{20}Ca$ = eighteen electrons, shows positive two charge.]

(b) To which pole in electrolysis would each of these charged atoms go? Why? [To the negative pole, because each shows at least one positive charge.]

EPISODE #13 (sixth of six pages)

5) (a) Draw a picture representing a charged atom of the elements which tend to act like non-metals* in the first 20 elements.

[$_{7}N$ = ten electrons, shows negative three charge

$_{8}O$ = ten electrons, shows negative two charge

$_{9}F$ = ten electrons, shows negative one charge

$_{15}P$ = eighteen electrons, shows negative three charge

$_{16}S$ = eighteen electrons, shows negative two charge

$_{17}Cl$ = eighteen electrons, shows negative one charge.]

(b) To which pole in electrolysis would each of these charged atoms go? Why? [To the positive pole, because each has taken on at least one additional negative charge.]

New Vocabulary

charged atom
electrolysis
pole

*There are very important compounds of nitrogen, sulfur and phosphorus, in which these elements each act like metals. These profound exceptions are studied in upper level sciences.

EPISODE #14

FACTUAL - CONCEPTUAL - INFERENTIAL

This instructional episode is designed to give children experience in using a simplified Periodic Table of the elements to make inferences about elements whose chemical characteristics and atomic structure have not been previously studied.

At the completion of this instructional episode the pupil should be able to select correct statements concerning certain characteristics of some of the more common elements by using a simplified version of the Periodic Table of the elements.

In part, the present episode is designed to give the pupils an introductory experience in predicting some characteristics of certain elements as a simple Periodic Table is built-up. Earlier, the pupils were introduced to concepts relevant to the planetary atomic model including atomic number, atomic mass ("weight"), electron shells and the general principle that the chemical characteristics are a function of the complement of electrons, especially those in the outer shell. Also, the pupils have had experience interpreting a simple, non-periodic table of the basic atomic structure of the first 20 elements.

A simplified version of the Periodic Table of the elements will be introduced. Each student receives a blank Table; an identical one is projected via overhead transparency by the instructor. As the rules for building the Table are developed by lecture and practiced by the pupils, the teacher should invite them to predict what might follow, in terms of (1) electron shell structure and nuclear complement, and (2) chemical and physical characteristics, based on what the pupils already know about common elements such as oxygen, iron, sulfur, magnesium, aluminum, lead, etc. The following basic facts and principles should be imparted via lecture-discussion-recitation. If the pupils become confused, or have difficulty concentrating on the procedures, be prepared to terminate the activity for the day...try again the next session, placing special emphasis on asking the children to explain to each other the basic system of organizing the Table.

1) The Periodic Table of the elements helps to organize and classify much information about the elements and one can avoid memorizing a great amount of detail by learning to interpret it.

2) The Periodic Table is arranged according to increasing atomic number (atomic number equals number of protons, and number of electrons) in such a way that similarity is shown between the number of shells and the number of electrons in the outermost shell. The atomic number

(continued)

appears below the symbol of each element. The atomic mass ("weight") appears above the symbol. Basic concepts relevant to atomic number, proton and electron complement and atomic mass ("weight") have been presented in earlier episodes.

3) The elements are arranged in columns and rows.

(a) Columns - This is the vertical alignment of the Table. Each column's elements are somewhat similar in chemical or reactive properties because they have the same number of electrons in the outermost shell. The number of electrons in the outermost shell appears in the heading for each column.

(b) Rows - This is the horizontal alignment of the Table. Each row contains elements which have the same number of electron shells. The number of shells for each row appears left-most on the Table.

The pupils should be invited, concomitant with the lecture, to fill in their blank Periodic Tables for the first 20 elements. They may be allowed to copy other well known elements as indicated on the instructor's reference table, directly from the instructor's projection overlay. The electron complement should be filled in; for example, No. 12 would be 2-8-2. The pupils should be asked to use the information they are building into their Tables to draw diagrams of various atoms on separate sheets. Certain students could be asked to put their drawings on the chalkboard and explain them. Although this portion of the current episode is a repetition of an earlier activity, it is expected that the reinforcement will have a salutory effect on learning.

As the mechanical process of filling in the Table begins to proceed with greater ease, the pupils should be asked to predict some of the characteristics (see questions Nos. 1 - 4 below) of elements that are yet to be charted in the Table; also, ask for predictions about several of the approximately 60 other elements not provided for in our simplified version of the Periodic Table. The query should include the following:

1) Relative mass ("weight") - Would the same volume of element No.__ be lighter, heavier, or have the same weight* as element No.__? Explain.

*More accurately it could be stated in terms of mass; more, less, or the same mass.

EPISODE #14 (third of seven pages)

[Compare element No. 1 vs. No. 2 (No. 1 is lighter); element No. 15 vs. No. 16 (No. 15 is lighter); element No. 18 vs. No. 19 (No. 18 is heavier); element No. 18 vs. No. 20 (same); element No. 33 vs. No. 35 (No. 33 is lighter).]

2) Atomic number, electron complement - What atomic number is assigned to the__th element in row__and what is its electron complement? [Example: the 1st element in row 2 has an electron complement of 2, 1.] What atomic number is assigned to the__ th element of column__ and what is its electron complement? [Example: the 2nd element of column 7 has an electron complement of 2, 8, 7. What is the number of electrons in the outermost shell of the element with atomic No. 54? [Look in lower right portion of the Table; note that the element iodine has atomic No. 53 and its outermost shell has 7 electrons. Element No. 54 can be expected to have 8 outermost electrons...it is an inert element.]

3) Metallic, non-metallic, indeterminant, inert - Would element No.__ be more or less metallic than element No.__? [Example: element No. 3 on the left side of the Table is more metallic than any of those in the same row. Element No. 9 is more non-metallic than any of those in the same row. Element No. 10 is inert. Elements in column No. 4 are indeterminant; in some situations they can act like a metal, and in other situations a non-metal, because the electrons complements of their outermost shells are half filled.]

4) Reactivity of elements - In which parts of the Periodic Table would there be located those elements most likely to react or combine with each other: The left portion vs. the right portion of the Table? The upper portion vs. the lower portion of the Table? The central part of the Table? [In general, the elements on the left are most likely to react with those on the right except, of course, for the inert elements all of which are in column no. 8. Elements toward the right of the Table are the non-metals which acquire electrons to fill the electron complements of their outermost shells...such electrons may be readily provided by the elements toward the left of the Table, the metals. Elements of certain columns tend to react most readily with elements of certain other columns to form compounds; elements of column no. 1 combine readily with those of column no. 7, column no. 2 with column no. 6,

column no. 3 with column no. 5. These combinations are in accord with the rules for filling outer electron shells, however, there are a great many important modifications in advanced studies. It is very common for certain elements of column no. 5 to combine with an element of column no. 6 despite the designation of elements in these columns as non-metals. In the present instructional episode emphasize the most general rules, as given earlier.]

Summary Questions

The sketches of the Periodic Table, as used in a number of questions in the summary, can be very quickly copied on the chalkboard or overhead projector in free hand...each such sketch should have the title "Periodic Table" as a continual reminder to pupils, and they should have their own Tables in front of them. Do not push for too much in one session...be prepared to terminate the lesson for a day if signs of tension, confusion, or boredom are generally noticeable.

1) In what way are the elements in row__ all alike? [They all have the same number of electron shells.]

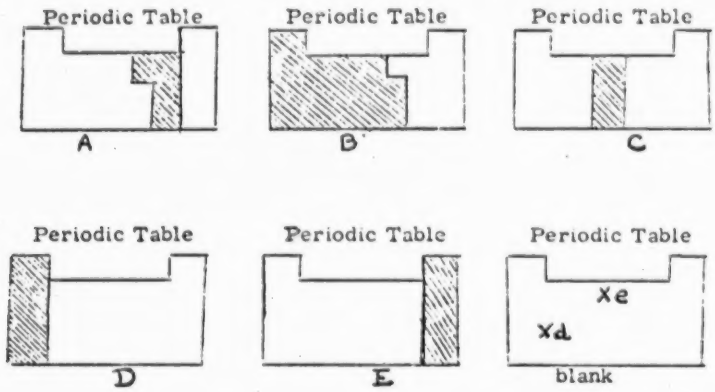
2) (a) How many electron shells does element No. 26 have? [4]

   (b) How many electron shells does element No. 21 have? [4]

   (c) How many electron shells does element No. 92 have? [7]

3) Predict the number of outer electrons of element No. 34. Explain. [According to the Periodic Table, element no. 33 has 5 electrons in its outer shell, and element no. 35 has 7 electrons in its outer shell. Element no. 34 which is between them can be expected to have 6 such electrons.]

4)



(a) Most of the non-metals are located in the shaded part ▨ of which Periodic Table above? [A... elements that tend to be non-metals have more than 4 electrons in their outermost shell, therefore are located in columns nos. 5, 6, 7.]

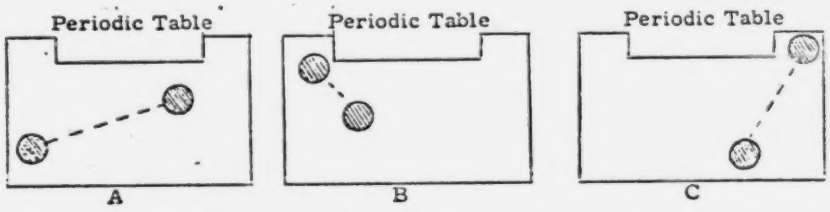
(b) The inert elements are located in the shaded part of which Periodic Table above? [E... elements that are inert have a complete electron complement in their outer shell.]

(c) The indeterminant elements are located in the shaded part of which Periodic Table above? Explain. [C... indeterminant elements can act like a metal or non-metal. Such elements have 4 electrons in their outermost shell, and therefore, are located in column no. 4.]

(d) There are several elements that are applied as common conductors of heat and electricity because they can be made into wire by heat, pressure and the action of tools. The neutral atoms of such elements have up to three electrons in their outermost shell. On a blank table (as above) indicate the approximate location of such elements by inscribing an "X". [Place the X toward the lower middle-left of the table. Here are located the well-known conductors such as copper, zinc, iron, silver... see X_d.]

(e) Make believe you are a scientist who needs an element that can act both like a metal and a non-metal and is light weight. On a blank table (as above) indicate the approximate location of such an element by inscribing an "X". [Place the X in the upper portion where the lighter elements are located and concomitantly in the middle where the indeterminant elements are located... see X_e.]

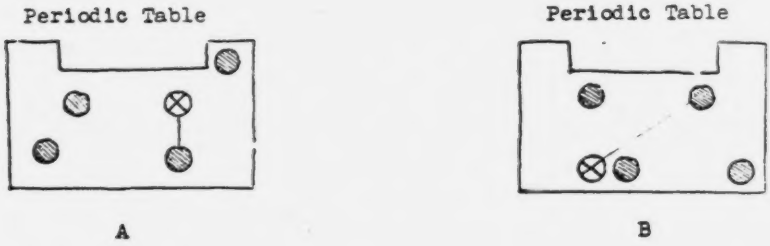
5)



(a) Each of two elements is represented by the symbol ⊗. Which table shows the two elements positioned so that they would most likely form a compound? Explain. [A.... the positioning indicates a metal combining with a non-metal.]

(b) Which table shows the two elements in positions most unlikely to form a compound? Explain. [C.... the positioning indicates a non-metallic element and an inert element; the latter is not likely to enter into combination. The middle table indicates a combination of two metals which is possible, but not too common, therefore is not included in our studies.]

6)



(a) In Periodic Table A, draw a line from the element marked ⊗ to a circle ○ which represents an element chemically most like ⊗ . Explain. [The line should be drawn vertically downward. Elements in the same column of the Periodic Table tend to have similar chemical characteristics because they have the same number of electrons in their outermost shell.]

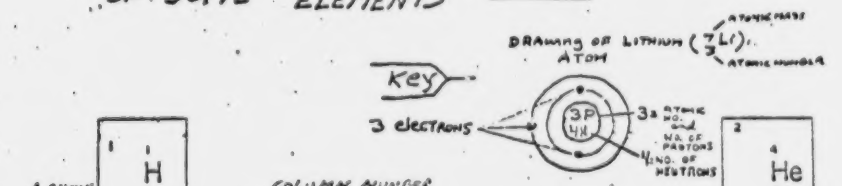
(b) In Periodic Table B, draw a line from the element marked ⊗ to the circle ○ that represents an element most likely to react or combine with ⊗ . Explain. [The line should be drawn toward the upper right or "two o'clock." The element directly to the right is fairly similar with a slightly greater number of outer electrons and is not likely to combine in a strong manner. The element to the far right is inert. The element in the same column has similar chemical properties. Element ⊗ appears to be a heavy metal, and could be expected to combine with a non-metal as in the upper right. Why? Metals tend to give up their outer electrons (1, 2, or 3 electrons) to non-metals which acquire or share electrons to complete the electron complement of their outer shells (5 or more electrons).]

New Vocabulary

combine, combination
Periodic Table of the Elements
react, reaction

A PERIODIC TABLE OF SOME ELEMENTS

Teachers' Copy

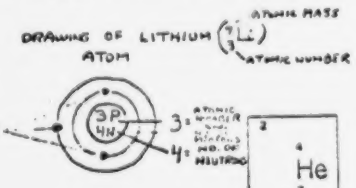


COLUMN NUMBER IS EQUAL TO THE NUMBER OF ELECTRONS USUALLY PRESENT IN OUTERMOST SHELL OF A NEUTRAL ATOM.

	ONE	TWO	THREE	FOUR	FIVE	SIX	SEVEN	EIGHT
1 SHELL	1 H 1 HYDROGEN							2 He 2 HELIUM
2 SHELLS	2,1 7 Li 3 LITHIUM	2,2 9 Be 4 BERYLLIUM	2,3 11 B 5 BORON	2,4 12 C 6 CARBON	2,5 14 N 7 NITROGEN	2,6 16 O 8 OXYGEN	2,7 19 F 9 FLUORINE	2,8 20 Ne 10 NEON
3 SHELLS	2,8,1 23 Na 11 SODIUM	2,8,2 24 Mg 12 MAGNESIUM	2,8,3 27 Al 13 ALUMINUM	2,8,4 28 Si 14 SILICON	2,8,5 31 P 15 PHOSPHORUS	2,8,6 32 S 16 SULFUR	2,8,7 35 Cl 17 CHLORINE	2,8,8 40 Ar 18 ARGON
4 SHELLS	2,8,8,1 39 K 19 POTASSIUM	2,8,8,2 40 Ca 20 CALCIUM	52 CHROMIUM 24 → 59 NICKEL 28; 56 IRON 26 → 64 COPPER 29; 59 COBALT 27 → 65 ZINC 30		2,8,18,5 75 As 33 ARSENIC		2,8,18,7 80 Br 35 BROMINE	2,8,18,8 84 Kr 36 KRYPTON
5 SHELLS	108 SILVER 47 → 112 CADMIUM 48			2,8,18,18,4 119 Sn 50 TIN			2,8,18,18,7 127 I 53 IODINE	
6 SHELLS	195 PLATINUM 78 → 197 GOLD 79 → 201 MERCURY 80			2,8,18,32,18,4 207 Pb 82 LEAD				2,8,18,32,18,8 222 Rn 86 RADON
7 SHELLS		226 Ra 88 RADIUM				238 U 92 URANIUM		

A PERIODIC TABLE of SOME ELEMENTS

PUPILS COPY



COLUMNS NO. = NUMBER OF ELECTRONS USUALLY PRESENT IN OUTERMOST SHELL OF A NEUTRAL ATOM

	ONE	TWO	THREE	FOUR	FIVE	SIX	SEVEN	EIGHT
1 SHELL	1 H 1 HYDROGEN							2 4 He 2 HELIUM
2 SHELLS	2,1 7 Li 3 LITHIUM	BERYLLIUM	BORON	CARBON	NITROGEN	OXYGEN	FLUORINE	NEON
3 SHELLS	SODIUM	MAGNESIUM	ALUMINIUM	SILICON	2,8,5 31 P 15 PHOSPHORUS	SULFUR	CHLORINE	ARGON
4 SHELLS	POTASSIUM	CALCIUM	52 CHROMIUM 24; 56 IRON 26; 59 COBALT 27	59 NICKEL 28; 64 COPPER 29; 65 ZINC 30	2,8,18,5 75 As 33 ARSENIC		2,8,18,7 80 Br 35 BROMINE	2,8,18,8 84 Kr 36 KRYPTON
5 SHELLS	108 SILVER 47; 112 CADMIUM 48			2,8,18,18,4 119 Sn 50 TIN			2,8,18,18,7 127 I 53 IODINE	
6 SHELLS	195 PLATINUM 78; 197 GOLD 79; 201 MERCURY 80			207 Pb 82 LEAD				222 Rn 86 RADON
7 SHELLS		226 Ra 88 RADIUM				238 U 92 URANIUM		

APPENDIX D

Conversion Tables of IQs to T-Scores

Appendix D, Table No. 1

Conversion Table

Deviation IQs to T-Scores

Middle Elementary Experimental Classes, N = 57

DIQ	f	T-Scores	DIQ	f	T-Scores
123	1	73	98	1	46
120	1	69	97	2	46
116	1	67	96	1	45
115	2	64	95	3	44
113	3	62	94	1	43
111	2	60	93	3	42
109	3	58	89	2	40
107	7	55	88	2	39
106	1	53	87	1	37
105	1	53	85	1	36
104	2	52	83	1	35
102	3	51	80	1	34
101	4	49	79	1	32
100	2	48	77	1	30
99	2	47	70	1	26

Appendix D, Table No. 2

Conversion Table

Deviation IQs to T-Scores

Middle Elementary Reference*("Control") Classes, N = 56

DIQ	f	T-Scores	DIQ	f	T-Scores
122	1	73	99	3	50
119	1	69	98	2	49
117	1	66	97	6	47
115	2	64	95	3	45
113	1	62	93	4	43
112	2	61	91	2	41
111	4	59	89	2	40
109	3	57	88	2	38
104	2	55	85	1	37
103	1	54	83	1	35
102	3	53	81	1	34
101	4	52	79	2	31
100	1	51	75	1	26

*T-scores from reference classes IQs were not applied directly in testing hypotheses.

Appendix D, Table No. 3

Conversion Table

Deviation IQs to T-Scores

Pre-Secondary Reference* ("Control") Classes, N = 54

DIQ	f	T-Scores	DIQ	f	T-Scores
127	1	73	101	1	45
122	1	69	100	1	45
118	2	65	99	1	44
117	3	62	98	1	44
116	1	60	97	2	43
114	3	59	96	4	41
113	1	57	95	1	39
112	5	56	94	1	39
110	1	54	92	2	37
109	3	53	91	1	36
108	5	51	90	1	34
107	2	50	88	1	33
106	2	49	85	1	30
104	3	47	80	1	26
102	2	46			

*T-scores from reference classes IQs were not applied directly in testing hypotheses.

Appendix D, Table No. 4

Conversion Table

Deviation IQs to T-Scores

Pre-Secondary Experimental Classes, N = 59

DIQ	f	T-Scores	DIQ	f	T-Scores
118	3	69	101	3	46
117	1	65	100	2	45
116	2	63	98	2	44
115	2	61	97	1	43
114	9	58	96	3	42
112	3	54	95	1	41
111	1	53	94	1	40
110	1	53	93	3	39
109	1	53	91	1	37
108	3	52	90	2	36
107	3	50	89	1	34
106	2	49	88	1	32
105	2	48	87	1	30
104	2	48	86	1	26
102	1	47			

Appendix D, Table No. 5

Conversion Table

Deviation IQs to T-Scores

Hypotheses Nos. 9a, 9b, 11a, 11b
Middle Elementary Boys$_x$, N = 30

DIQ	f	T-Scores	DIQ	f	T-Scores
123	1	71	97	2	46
120	1	66	95	3	44
113	3	61	93	1	42
109	1	59	87	1	40
107	5	55	85	1	39
106	1	52	83	1	38
104	2	51	79	1	36
102	1	50	77	1	33
101	1	49	70	1	28
99	2	48			

Appendix D, Table No. 6

Conversion Table

Hypotheses Nos. 10a, 10b, 12a, 12b
Middle Elementary Girls$_x$, N = 27

DIQ	f	T-Scores	DIQ	f	T-Scores
116	1	70	100	2	47
115	2	64	98	1	46
111	2	60	96	1	45
109	2	57	93	3	42
107	2	55	89	2	39
105	1	53	88	2	35
102	2	52	80	1	29
101	3	50			

Appendix D, Table No. 7

Conversion Table

Deviation IQs to T-Scores

Hypotheses Nos. 13a, 13b, 15a, 15b
Pre-Secondary Boys$_{\bar{x}}$, N = 29

DIQ	f	T-Scores	DIQ	f	T-Scores
118	2	68	104	1	48
117	1	63	102	1	47
116	1	61	101	1	46
115	1	60	97	1	45
114	4	57	96	2	44
112	1	54	94	1	42
111	1	53	93	2	40
110	1	52	90	1	38
109	1	51	89	1	36
108	1	50	88	1	33
107	1	50	86	1	28
105	1	49			

Appendix D, Table No. 8

Conversion Table

Deviation IQs to T-Scores

Hypotheses Nos. 14a, 14b, 16a, 16b
Pre-Secondary Girls$_x$, N = 30

DIQ	f	T-Scores	DIQ	f	T-Scores
118	1	71	101	2	46
116	1	66	100	2	44
115	1	63	98	2	42
114	5	59	96	1	40
112	2	55	95	1	39
108	2	53	93	1	38
107	2	51	91	1	36
106	2	50	90	1	33
105	1	48	87	1	28
104	1	47			

APPENDIX E

The Measurement Instrument

THE MEASUREMENT INSTRUMENT

The post-instructional form of the test appears in this appendix. Pages in the pre-instructional form were in a partly randomized order. Included here are directions for teachers and pupils on the pre and post instructional forms.

The reference tables required for Part II of both forms of the test are virtually identical to those recorded in Appendix C, Sequence of Instructional Episodes; see page 5 episode no. 11 for the chart entitled The First 20 Elements, and see the final page of episode no. 14 for pupils' copy of A Periodic Table of Some Elements.

Following the administration of the post-instructional test, the investigator discovered that one question, no. 7.4, had an ambiguity in content. A pupil who knew only that it requires work to overcome electrostatic attraction between bodies would be likely to select answer D. He would reject answer A reasoning that protons repulse each other. On the other hand, a pupil who understood the preceding, but also knew that great "forces" hold protons together in atomic nuclei would select answer A, reasoning that much work would be required to separate protons united as such. In scoring, either answer A or D was counted as a correct answer.

TEST OF PUPIL'S ATTAINMENT

AFTER CERTAIN INSTRUCTIONAL EPISODES

LEADING TO AND PERTAINING TO THE

PLANETARY ATOMIC MODEL

An investigation in elementary science curriculum employing a major conceptual schemes approach.

by S. Harvey Steinberg

PRE - instructional form, administered_____19__

POST - instructional form, administered_____19__

X R Grade level_____

Name of Pupil_____ BOY GIRL

Teacher's Name_____School_____

DIRECTIONS FOR TEST ADMINISTRATION

1. Read the directions on the first page of the test booklet to the pupils.

2. Read each question aloud as many times as needed for each pupil to mark an answer to each question. The pupils should circle the letter of the best of four answers. They can use pen or pencil. Move around the room to ascertain that all pupils are working.

3. Space the seating of the pupils to insure that each does his own work. Encourage them to work hard even though some or nearly all of the questions are unfamiliar. Some classes will be taking the test a second time without benefit of formal instruction on the material. Ask them to do their best.

4. The PRE and the POST form are each given in two sittings. Each sitting will take at least 30 minutes (more likely 45 minutes), but time should not be a factor in completing the test. The first sitting of each of the PRE and POST forms ends with question no. 11.1.

5. To help dissipate the effects of fatigue, the class should, for one minute during each sitting, stand up, exercise, wiggle, talk, etc., then promptly go back to the task. Test papers should be closed during the break.

6. The pages of each booklet of the PRE form are in the same partially randomized order. The first sitting of both the PRE and POST forms of the test ends at question no. 11.1 and the second sitting begins at question no. 11.2.

(continued)

SECOND SITTING, PRE AND POST FORMS

7. Beginning at the second sitting (question no. 11.2) of both the PRE and POST form, two tables must be issued to each pupil. The teacher is to describe the use of each table upon distribution; tell the pupils only the following:

(TABLE OF 20 ELEMENTS)

a) "This sheet (show pupils...ask them to look at their table of 20 elements) is a table of the first 20 elements and their basic atomic parts."

(PERIODIC TABLE)

b) "This sheet (show pupils...ask them to look at their Periodic Table) is a Periodic Table of some of the elements. It is made in such a way that a relation is shown between an atom's electron shells and the number of electrons in the outermost shell. I will give you time to look over both tables. I cannot tell you <u>how</u> they are used, but I will tell you <u>when</u> they are used."

(TEACHER LETS PUPILS PERUSE TABLES, THEN SAYS:)

c) "Many of the questions in this part (second sitting) of the test state that <u>The Pupil May Use the Tables</u> or <u>The Pupil Uses Tables</u>. I will tell you on which questions either of these statements appears, but you will have to decide which table is best suited to help answer the question."

For each such question tell the pupils before reading the question that the tables can or may be used, and remind them again, a minute or so before going on to the next question.

Pupils who have not been taught how to use the tables may seem upset. Assure them that their "mark" in science will not be affected, but they will be expected to try hard on all questions.

It is important in the investigation that the directions for administering the test be implemented as exactly as possible. Your time and attention to these details is very much appreciated.

DIRECTIONS FOR PUPILS

PRE - FORM

1. The purpose of this test is to find out what you may know about certain parts of science. Try your best on every question.

2. There are probably many questions which ask about things that are new to you. Some may be fun to think about even if you are not sure of the answer. Try hard on all questions.

3. Each question has four answers, but only one is the best answer. Put a circle around the letter of the best answer only. Do every question.

4. The test will be given in two parts. At the start of the second part, you will be given two charts or tables. If you know how, the charts can help answer questions marked "PUPIL USES TABLES", or "PUPIL MAY USE TABLES".

5. Your teacher will read each question slowly. You should read along with your teacher. If you need more time, or need a question read again, ask you teacher.

DIRECTIONS FOR PUPILS

POST - FORM

1. The purpose of this test is to find out what you may have learned in science over the past few weeks. Don't be upset if you are not sure about an answer, but try your best on every question.

2. Each question has four answers, but only one is the best answer. Put a circle around the letter of the best answer only. Do every question.

3. The test will be given in two parts. At the start of the second part, you will be given two charts or tables. The charts can help you answer the questions marked "PUPIL USES TABLES", or "PUPIL MAY USE TABLES".

4. Your teacher will read each question slowly. You should read along with your teacher. If you need more time, or need a question read again, ask your teacher.

Episode No. 1

Inferential (background)

1.1 Why can a sponge soak up a lot of water?

A) Because sponges can bend when wet.
B) Because some kinds of sponges grow in water.
(C) Because sponges have many open spaces.
D) Because sponges need water.

Episode No. 2

Inferential (background)

2.1 When a substance changes from a liquid to a gas, what happens to its molecules?

A) The molecules are destroyed.
B) The molecules get smaller.
C) The molecules get closer to each other.
(D) The molecules move apart from each other.

Episode No. 3

Conceptual - Inferential (background)

3.1 The smell from perfume in a dish most easily spreads through a room when,

A) ice is put in the dish.
B) the room is made warmer.
C) the room is darkened.
D) the room is made colder.

3.2 Oil flows easier in hot weather because;

A) the oil molecules are far apart.
B) the oil molecules dry fast.
C) the oil molecules are close together
D) the oil molecules dry slow.

Episode No. 4

Factual - Conceptual - Inferential (background)

4.1 A child takes a cold soft drink can from the refrigerator. He leaves it unopened. When he returns a few minutes later, he finds moisture on the can. How did the moisture get there?

A) Water from the air changes to a gas when it strikes the warm can.
B) The can leaked from around the top edge. It dripped down the side of the can.
(C) Water molecules from the air collect on the can because they lost their heat to the cold can.
D) Heat from the can makes air molecules condense upon it.

Episode No. 5

Inferential (background)

5.1 A child tries to guess what is in a box. Of what can he be directly sure, without opening it?

A) What is in it.
B) If it has a living thing in it.
C) If it has a non-living thing in it.
(D) The many kinds of things that cannot be in it.

Episode No. 5

Inferential (background)

5.2 Pretend each of the things listed has the same weight. Which one takes up the most space or volume?

A) A coin.
B) A new bar of soap.
C) A 10¢ chocolate bar.
(D) A balloon floating in air.

5.3 Pretend each of the things listed has the same weight. Which one has the most density?

(A) A coin.
B) A new bar of soap.
C) A 10¢ chocolate bar.
D) A balloon floating in air.

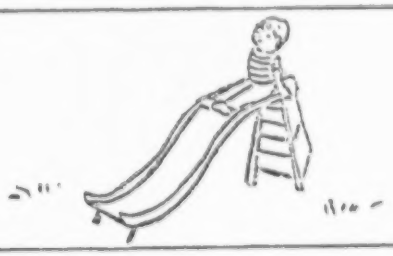
Episode No. 6

Factual - Conceptual - Inferential (background)

6.1 In which drawing does it show that work is being done?

A)

B)

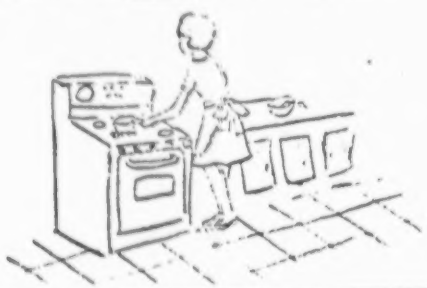


C)

D)

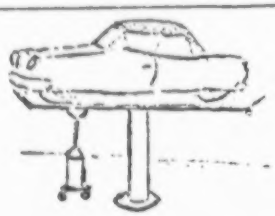
6.2 In which drawing is the most work being done?

A)



B)

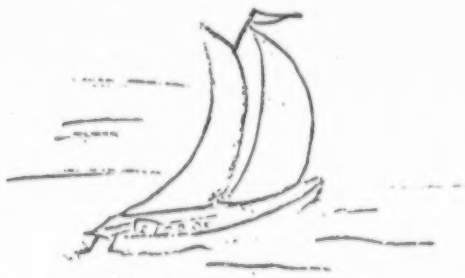
C)



D)

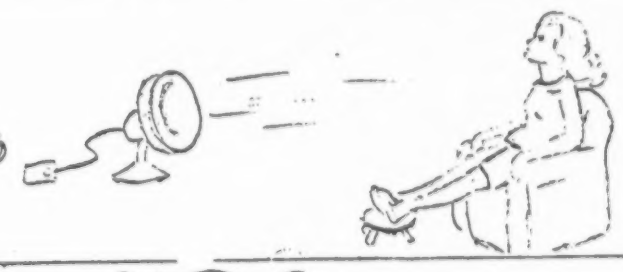
6.3 Which drawing shows one kind of work being changed to another kind of work?

A)

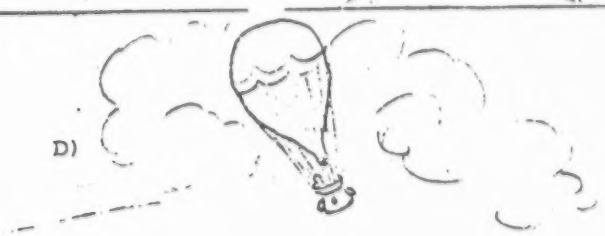


B)

C)



D)



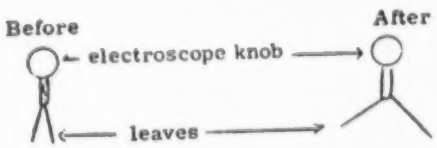
Episode No. 7

Factual - Conceptual - (background)

7.1 To add electric charges, or to take away electric charges,

(A) work must always be done.
B) a switch must always be turned on.
C) a switch must always be turned off.
D) always use an electroscope.

7.2



Which particles could make the leaves of the electroscope act as the drawing shows?

KEY
Positive charged electrical particle = ⊕
Negative charged electrical particle = ⊖

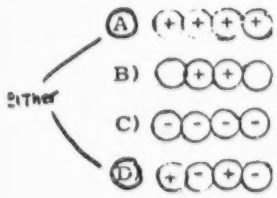
A) ⊕ ⊖
B) ⊖ ⊕
(C) ⊕ ⊕ or ⊖ ⊖
D) ⊕ ⊖ ⊕ ⊖

7.3 Negative electric charges show up on an ebony rod when it is rubbed with fur. From where do the negative charges come?

(A) The smallest parts of the fur.
B) batteries inside the ebony rod.
C) The smallest parts of the ebony rod.
D) Magnets inside the ebony rod.

7.4 Which chain of electrical particles would need the most work or energy to be broken apart?

KEY
Positive charged electrical particle = ⊕
Negative charged electrical particle = ⊖
Neutral particle = ○



Episode No. 8

Factual - Conceptual - Inferential (background)

8.1 Atoms are thought to be partly made up of:

(A) Negative charged particles and positive charged particles.
B) Neutral molecules.
C) Negative charged molecules and positive charged molecules.
D) Positive electrical molecules.

8.2 The electrical charge of an electron is thought to be:
A) positive
(B) negative
C) neutral
D) sometimes positive and sometimes neutral

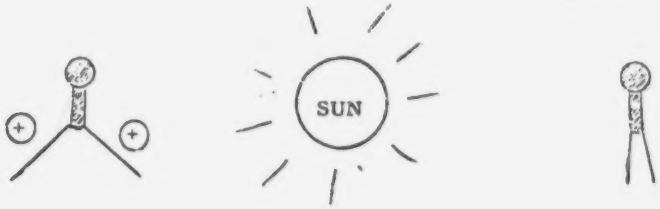
8.3 If we rub a substance, what part of its atoms is most likely to be moved?

A) protons
B) neutrons
(C) electrons
D) nuclei

8.4 When an atom loses electrons it:

(A) becomes more positively (+) charged.
B) becomes more negatively (-) charged.
C) becomes neutral.
D) is destroyed.

8.5



In sunlight the leaves of a positively charged electroscope go down because energy from the sun gives some of the air around the electroscope an electric charge. Which air particles make the leaves go down?

KEY

air particle with positive charge →

air particle with negative charge →

air particle with no charge →

A)

B)

C)

D)

Episode No. 9

Factual - Conceptual

9.1 Scientists tell us that about 100 elements make-up all the things of the world. How do each of the elements differ from each other?

A) All elements are alike except for their names.
(B) Each element has its own kind of atom.
C) All elements are alike except for their color.
D) Each element is a different mixture of compounds.

9.2 What is the tiniest part of an element which is exactly like the element?

A) a compound
B) a mixture
C) a molecule
(D) an atom

9.3 What is the tiniest part of a compound which is exactly like the compound?

(A) A molecule
B) An atom
C) A mixture
D) An element

9.4 When the element hydrogen and the element oxygen are joined in the right way, they form water. Water is called:

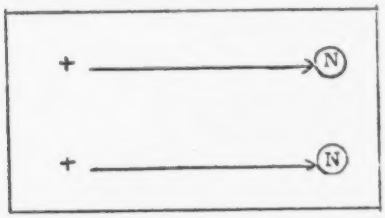
A) A mixture
B) An element
C) A mixture of compounds
(D) A compound

Episode No. 10

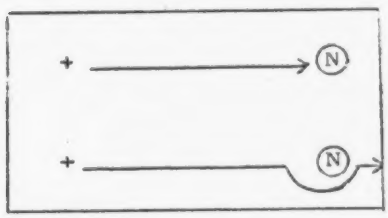
Factual - Conceptual - Inferential

10.1 A scientist shoots high speed positive charges, + ——→ , at atomic nuclei, (N). Which drawing shows the most likely result?

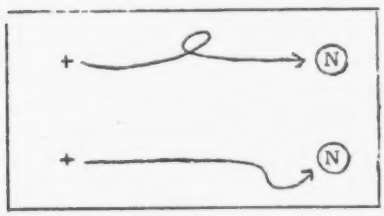
A)



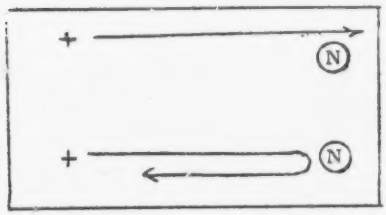
B)



C)



(D)



Episode No. 11

Factual - Conceptual - Inferential

11.1 Which one of these parts of an atom is thought to have the least mass ("weight")?

A) neutron

(B) electron

C) positive charge

D) proton

END FIRST HALF OF TEST HERE

BEGIN SECCND HALF OF TEST HERE.

EACH PUPIL RECEIVES TWO TABLES.

11.2 (PUPIL MAY USE TABLES)

The atomic number of an element is always the same as its:

A) atomic mass ("weight").
B) number of neutrons.
(C) number of protons.
D) number of electron shells.

11.3 What is the atomic number of the element with 26 protons and an atomic mass ("weight") of 56?

A) 56
B) 82
C) 30
(D) 26

11.4 (PUPIL MAY USE TABLES)

An element with 15 protons and an atomic mass ("weight") of 31 has how many neutrons?

A) 31

(C) 16

B) 15

D) 46

11.5 (PUPIL USES TABLES)

In the first 20 elements, which elements have all their electron shells filled?

(A) helium (He), neon (Ne), argon (Ar)
B) helium (He), oxygen (O), neon (Ne)
C) hydrogen (H) helium (He), beryllium (Be)
D) beryllium (Be), oxygen (O), argon (Ar)

11.6 (PUPIL USES TABLES)

Equal sized boxes are completely filled with certain elements, as pictured.

box of carbon | box of aluminum | box of sulfur | box of magnesium

Which one weighs the most?

(A) sulfur (S)

B) aluminum (Al)

C) carbon (C)

D) magnesium (Mg)

11.7 (PUPIL USES TABLES)

Which one of these elements has the most neutrons?

A) No. 20

(C) No. 18

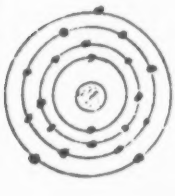
B) No. 19

D) No. 17

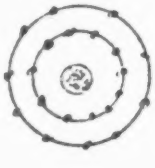
11.8 (PUPIL USES TABLES)

A drawing of an atom of element No. 21 would be like which one of these?

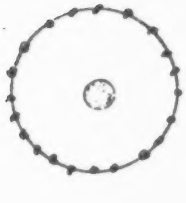
A)



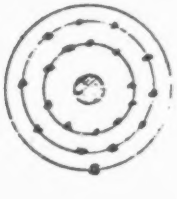
C)



B)



D)



Episode No. 12

Factual - Conceptual

12.1 An inert element is NOT usually active because its outer electron shell:

A) has fewer than 4 electrons.

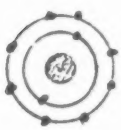
(B) is complete.

C) has 4 electrons

D) has no electrons.

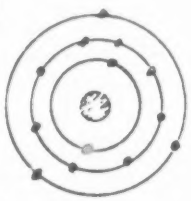
12.2 Which one of these elements would most easily lose outer electrons?

A)



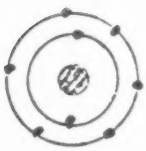
neon (Ne)

(C)



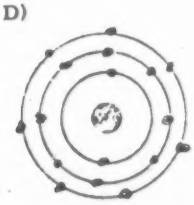
aluminum (Al)

B)



oxygen (O)

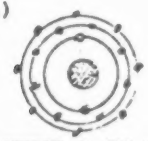
D)



chlorine (Cl)

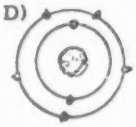
12.3 (PUPIL MAY USE TABLES)

Which one of these elements is most likely to act as a metal?

A)  argon (Ar) atomic no. 18

C) hydrogen (H) atomic no. 1

B) fluorine (F) atomic no. 9

D)  nitrogen (N) atomic no. 7

12.4 (PUPIL MAY USE TABLES)

Some elements can act like metals or can act like non-metals. Which drawing best shows the outer electron shell of an element most likely to act this way?

A)

C)

B)

D)

12.5 (PUPIL USES TABLES)

The element sodium (Na) and the element fluorine (F) can form the compound sodium fluoride (NaF). Which sentence best explains how the compound is formed?

A) Fluorine's outer electron fills sodium's outer shell.
B) Sodium loses all its electrons.
(C) Sodium's outer electron fills fluorine's outer shell.
D) Fluorine loses all its electrons.

Episode No. 13

Factual - Conceptual

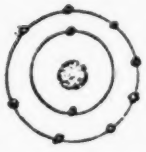
13.1 Charged atoms have:

A) lost neutrons.
(B) gained electrons or lost electrons.
C) gained neutrons.
D) gained neutrons and lost protons.

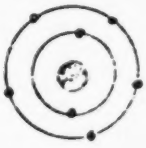
13.2 (PUPIL MAY USE TABLES)

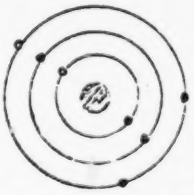
Which one of these drawings shows a charged atom of nitrogen (N)?

atomic No. = 7

A) 

C)

B) 

D) 

13.3 (PUPIL USES TABLES)

The ocean has in it the compound magnesium chloride . The elements magnesium (Mg) atomic No. = 12, and chlorine (Cl) atomic No. = 17 are separated by electrolysis. At which poles are these elements collected during electrolysis?

POSITIVE POLE = +

NEGATIVE POLE = −

A) chlorine at − magnesium at +

(B) chlorine at + magnesium at −

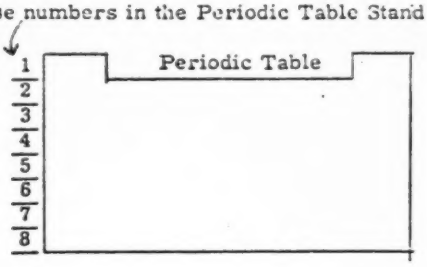
C) chlorine at − magnesium at −

D) chlorine at + magnesium at +

Factual - Conceptual - Inferential

14.1 (PUPIL USES TABLE)

What do these numbers in the Periodic Table Stand for?

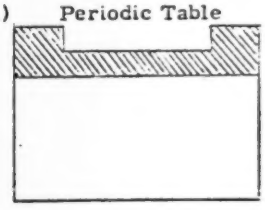


A) The number of electrons in the atom.
B) The number of protons.
C) The atomic number.
(D) The number of electron shells.

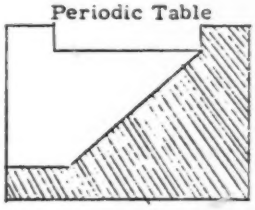
14.2 (PUPIL USES TABLE)

In the shaded ▨ part of which Periodic Table drawing do the elements act most like each other?

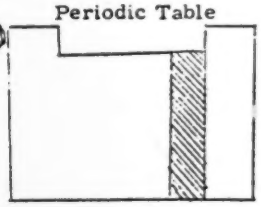
A)



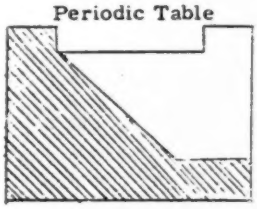
C)



(B)



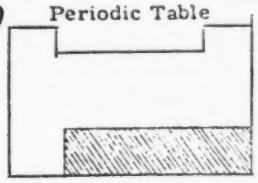
D)



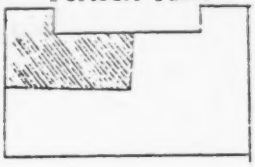
14.3 (PUPIL MAY USE TABLE)

In the shaded part of which Periodic Table drawing are some of the heavy elements found?

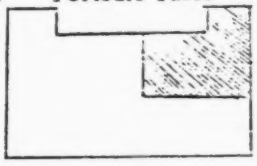
(A) Periodic Table



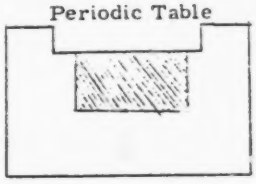
C) Periodic Table



B) Periodic Table



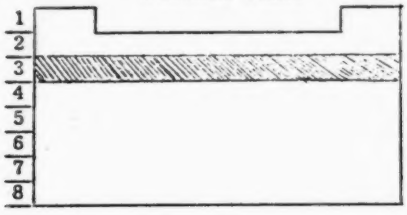
D) Periodic Table



14.4 (PUPIL MAY USE TABLE)

What is the smallest number of total electrons that an atom can have in the shaded part of the Periodic Table in the drawing?

Periodic Table

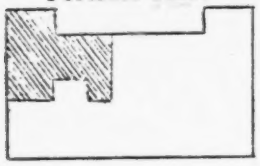


A) 3
B) 16
(C) 11
D) 6

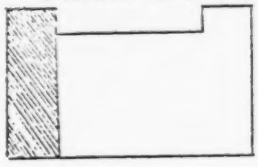
14.5 (PUPIL MAY USE TABLE)

In the shaded part of which Periodic Table drawing would some non-metallic elements be found?

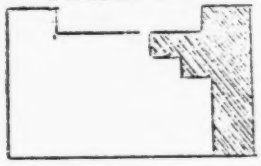
A) Periodic Table



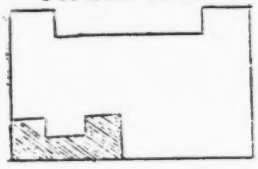
C) Periodic Table



(B) Periodic Table



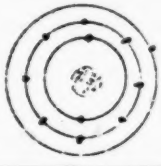
D) Periodic Table



14.6 (PUPIL MAY USE TABLES)

Pretend you are a scientist looking for a very light weight element that does NOT easily form compounds. Which one of these would you choose?

(A) atomic no. 2

C)  atomic no. 11

B) atomic no. 1

D) atomic no. 17

14.7 (PUPIL MAY USE TABLES)

Pretend you are a scientist looking for an element that is very likely to form compounds with either metals or non-metals. Which one of these would you choose?

A) atomic no. 8

C) atomic no. 10

B) atomic no. 1

D) atomic no. 8

APPENDIX F

Experimental Run: Number Correct Per Test Item for Estimating Reliability.

Appendix F, Table No. 1

Experimental Run: Number Correct Per Test Item for Estimating Reliability*

Item Designation on Test	No. Correct	Item Designation on Test	No. Correct
1.1	111	10.1	95
2.1	88	11.1	65
3.1	96	11.2	93
3.2	56	11.3	48
4.1	77	11.4	101
5.1	78	11.5	89
5.2	95	11.6	104
5.3	64	11.7	94
6.1	100	11.8	100
6.2	61	12.1	93
6.3	73	12.2	104
7.1	86	12.3	92
7.2	69	12.4	74
7.3	87	12.5	59
7.4	95	13.1	59
8.1	67	13.2	22
8.2	70	13.3	56
8.3	81	14.1	102
8.4	55	14.2	76
8.5	70	14.3	58
9.1	54	14.4	17
9.2	78	14.5	77
9.3	61	14.6	50
9.4	65	14.7	62
		Sum =	3627

*These scores were taken from the post-instructional tests of the 116 pupils of the experimental classes. Additional data for estimating the coefficient of reliability for experimental and pilot classes are reported in Table XLIV.

VITA

S.(amuel) Harvey Steinberg was born in Syracuse, New York, February 1, 1928. He is the only surviving child of Rose I. Chadwick Steinberg and Nathan Steinberg. He was educated in Syracuse public schools, graduating from Central High in January 1946. During two periods from 1946 through 1951, he served a total of 33 months enlisted in the U. S. Marine Corps. He entered Syracuse University in 1948 and received a Bachelor of Science in Combined Science degree in 1953. In 1954 he received the Master of Science in Science Education degree from Syracuse University. From 1954 to 1956 he was chairman of the science department at New York Mills, New York High School. In 1955 he was awarded a New York State War Service scholarship and thereby continued advanced studies in science education. From 1956 to 1961 he taught at Syracuse Central Technical High School and was chairman of the academic science department for three years. He was married to the former Jean Marie Farrington on October 10, 1959. Since September 1961 he has been an assistant professor at State University College, Cortland, New York.

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